AGENDA AND AGENDA NOTES

77th MEETING OF THE TECHNICAL ADVISORY COMMITTEE (TAC) OF NIH

APPENDICES

(Vol.-II)

19th February, 2024
at 1100 Hrs
Online Mode

NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

APPENDIX – 77.2.1

MINUTES OF THE 76th MEETING OF TAC OF NIH

MINUTES OF 76th MEETING OF TECHNICAL ADVISORY COMMITTEE (TAC) OF NATIONAL INSTITUTE OF HYDROLOGY

Held on 29 August 2022 (Offline & Online mode)

The 76th meeting of the Technical Advisory Committee (TAC) of the National Institute of Hydrology, Roorkee was held in hybrid mode on 29th August 2022 at Roorkee. The meeting was chaired by Dr. R.K. Gupta, Chairman, CWC. The list of the participants is given in Annexure-I.

Dr. J.V. Tyagi, Director, NIH first welcomed the Chairman, Members and invitees. He briefed about the role of the Working Group and Regional Coordination Committees constituted to review the work programme at headquarters and regional centers of NIH. After a round of brief introduction of members and invitees, Director invited the Chairman, TAC for his opening remarks. At the outset, the Chairman welcomed all the participants in his opening remarks. He appreciated the research being carried out by the Institute and desired to work together with other organizations (like CWC, IMD) in various areas related to hydrology. He mentioned that NIH is taking lead role in various research studies related to climate change, groundwater hydrology, sedimentation, salt intrusion, etc. He advised that NIH, CGWB, and the Tamil Nadu Water Resources Department can work together on salt intrusion problems. The Chairman desired that NIH should expore the deficit irrigation scenario, and this may be worked out jointly with NIH and WTC-IARI (New Delhi). The Chairman made a strong case for forming a joint group of NIH and CWC to work on identified studies and problems.

After opening remarks by the Chairman, Director, NIH invited Dr. V. C. Goyal, Scientist G & Head, RMOD/Member-Secretary took up the agenda items in the meeting.

ITEM NO. 76.2: Confirmation of the Minutes of 75th Meeting of TAC

The Member-Secretary informed that minutes of the 75th meeting of TAC, held on September 1, 2021 in virtual mode were circulated to all the members and invitees vide email dated September 22, 2021. Since no comments were received from the members, the Minutes were confirmed by the TAC.

ITEM NO. 76.3: Action Taken on Decisions/Recommendations in the Previous Meeting

The Member-Secretary presented the action taken on the comments and suggestions of the members during the previous meeting. On issue of pending case of the creation of a post of documentation officer, Chairman suggested to constitute an internal committee to look after the requisite task of compilation of hydrological research in India on identified topics. Regarding the issue of hydrological inputs as applicable to IDEA, Director NIH advised Dr P K Singh, Scientist D-NIH, to exlore if outputs of WA+ can be uploaded on the IDEA portal.

ITEM NO. 76.4: Status of the Work Programme for the Year 2021-22

The Member-Secretary briefly mentioned about the studies carried out by the Institute during the year 2021-2022. He reported that twenty two sponsored projects and twenty internally funded R&D studies were completed during the year. Members appreciated the number of publications brought out by the Institute and number of training/workshop/symposium organized by the Institute. The following studies completed during 2021-2022 were presented during the meeting:

a) Statistical evaluation of Global precipitation estimates over data scares Western Himalayan region of India – ***Shri D.S. Bisht, Scientist 'B'***
b) Water Quality Assessment of South West Punjab emphasizing Carcinogenic Contaminants and their possible Remedial Measures - ***Dr. Rajesh Singh, Sc. 'D'***
c) Evaluation of the influence of low frequency atmosphere ocean oscillations on annual floods in Godavari and Narmada river banks - ***Dr. Sunil Gurrapu, Sc. C***

Regarding the first study, Prof. K.V. Jayakumar appreciated the study. as it has direct relevance for data scare regions.

In the second study, Prof. A. K. Sharma advised to include a comparison of WQI and HHI of groundwater in the study area. Prof. K. V. Jayakumar advised to include the sources responsible for the change in the water quality during pre- and post- monsoon in the report. Dr. R. K. Gupta, Chairman CWC and Er. J. Chandrashekhar Iyer, Member (D&R), CWC advised to include a disclaimer in the report to avoid panic in the society.

In the third study, Prof. K V Jayakumar advised to explore more relevant literature of Godavari basin from various studies on flood and droughts. Dr. Man Singh asked to give future projections in this study.

TAC noted the progress of the works of the Institute during the year 2021-2022.

General comments on completed studies:

1. There should not be duplication of studies between CWC and NIH
2. Completed studies should be put on website and monitor the number of users for reference.

ITEM NO. 76.5: Proceedings of the Working Group and Regional Coordination Committee (RCC) Meetings

The Member-Secretary briefly mentioned about the 52nd meeting of the Working Group of NIH which was held during 12-13 April 2022 and the RCC meetings held at the different Regional Centres. During these meetings, the Working Group/RCC members reviewed the progress of studies for the year 2021-2022 and recommended the work program for 2022-23.

The Chairman expressed the need to take joint studies with CWC on focused topics such as climate change and its impact on water resources. Director, NIH requested Chairman to identify a nodal officer from CWC to interact with NIH for collaborative studies through recently developed Centre of Cryosphere Studies for Climate Change Studies at NIH. Member (D&R) also raised concern to take up joint studies with CWC in focused areas including dam break studies, etc.

The Chairman expressed his concern on a study entitled " Long term hydrological assessment for the development of water security plan for three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram " being carried out at RC Guwahati under NHP. He advised to maintain confidentiality of such studies undertaken in the North East region and provide a copy to CWC on completion.

ITEM NO. 76.6: Work Program for the year 2022-23

The Member-Secretary briefly mentioned about the proposed work programme of the Institute for the year 2022-23 which was discussed during the 52nd Working Group meeting and various RCC meetings of NIH. The proposed work programme of the Institute for F.Y. 2022-23, as recommended by the Working Group and the respective RCCs, was also placed before the TAC.

TAC approved the work programme of the Institute for the year 2022-23 (Annexure-II).

ITEM NO. 76.7: Major projects and activities of national importance

It was informed by the Member-Secretary that the Institute has recently completed a project entitled National Mission for Sustaining the Himalayan Ecosystem (NMSHE)- funded by DST (GoI), and the following two major R&D projects are currently ongoing at NIH:

1. National Hydrology Project (NHP)- funded by The World Bank & GoI
2. Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)- funded by DST (GoI)

ITEM NO. 76.8: Reporting Items

Details of the ongoing consultancy projects in NIH up to 25th July 2022 were noted by the TAC.

ITEM NO. 76.9: Additional items with the permission of the Chair

No such items were discussed. The meeting ended with a vote of thanks to the Chair.

Annexure-I

LIST OF PARTICIPANTS IN THE 76th MEETING OF TAC OF NIH

1.	Sh. R K Gupta, Chairman, CWC	In-chair
2.	Sh. J. Chandrashekhar Iyer, Member (D&R), CWC	Member
3.	Dr. J V Tyagi, Director, NIH	Member
4.	Dr. T. Chakraborty, CGWB, Faridabad	Member (Rep. of CGWB)(online)
5.	Prof. K V Jayakumar, NIT, Warangal	Member
6.	Dr. Man Singh, ICAR-IARI, New Delhi	Member
7.	Dr. A K Das, IMD, New Delhi	Member (Online)
8.	Prof. Arup Sarma, IIT, Guwahati	Member (Online)
9.	Sh. Shambhu Azad, WAPCOS, New Delhi	Member (Rep. WAPCOS) (Online)
10.	Dr.V C Goyal, Sc.G & Head RMO Division, NIH	Member-Secretary

INVITEES

1. Dr. Sudhir Kumar, Sc. G & Head, HI Division, NIH, Roorkee
2. Dr. Sanjay Jain, Sc. G & Head, WRS Division, NIH, Roorkee
3. Dr. M K Goel, Sc. G & Head, GWH Division, NIH, Roorkee
4. Dr. R P Pandey, Sc. G & Head, EH Division, NIH, Roorkee
5. Sh. B. Chakraborty, Sc. G, NIH, CFMS-Patna (Online)
6. Dr. Y R S Rao, S.G, NIH, RC-Kakinada (online)
7. Dr. S V Vijaya Kumar, Sc. G, NIH, RC-Guwahati (online)
8. Dr. Suhas Khobragade, Sc. G, NIH, Roorkee
9. Er. Omkar Singh, Sc. G, NIH, Roorkee
10. Dr. A R Senthil Kumar, Sc. F, NIH, Roorkee
11. Dr. Anupma Sharma, Sc. F, NIH, Roorkee
12. Dr. M S Rao, Sc. F, NIH, Roorkee
13. Dr. Surjeet Singh, Sc.F, NIH, Roorkee
14. Dr. P C Nayak, Sc.F, NIH, Roorkee
15. Dr. Sanjay Kumar, Sc.F, NIH, Roorkee
16. Dr. Manohar Arora, Sc.F, NIH, Roorkee
17. Dr. M K Sharma, Sc.E, NIH, Roorkee
18. Dr. Soban Singh Rawat, Sc.E, NIH, Roorkee
19. Dr. Mathew K. Jose, Sc.E, NIH, RC-Belagavi
20. Dr. Ravi Galkate, Sc.E, NIH, RC-Bhopal (online)
21. Dr. T Thomas, Sc.E, NIH, RC-Bhopal (online)
22. Dr. P K Singh, Sc.D, NIH, Roorkee
23. Dr. J P Patra, Sc.D, NIH, Roorkee
24. Dr. L N Thakural, Sc.D, NIH, Roorkee
25. Dr. Sumant Kumar, Sc.D, NIH, Roorkee
26. Dr. Rajesh Singh, Sc.D, NIH, Roorkee
27. Dr. Pradeep Kumar, Sc.D, NIH, Roorkee
28. Dr. Ashwini A. Ranade, Sc.D, NIH, Roorkee
29. Dr. Gopal Krishan, Sc.D, NIH, Roorkee
30. Dr. Jyoti P. Patil, Sc.D, NIH, LCU, New Delhi (online)
31. Er. Digamber Singh, Sc.D, NIH, Roorkee
32. Dr. P K Mishra, Sc.D, NIH, Roorkee
33. Dr. Vinay K. Tyagi, Sc.D, NIH, Roorkee
34. Dr. R K Jaiswal, Sc.D, NIH, RC-Bhopal (Online)
35. Dr. Jose Pottakkal, Sc.D, RC-Jammu (online)
36. Dr. R Venkata Ramana, Sc.D, RC-Kakinada (online)
37. Dr. Sunil Gurrapu, Sc.C, NIH, Roorkee
38. Dr. Vishal Singh, Sc.C, NIH, Roorkee
39. Dr. Sanjay Sharma, Sc.C, NIH, RC-Guwahati (online)

40. Dr. Shashi Poonam Indwar, Sc.C, RC-Bhopal (online)
41. Sh. Pravin Patil, Sc.C, NIH, CFMS-Patna (online)
42. Dr. Deepak Singh Bisht, Sc.B, NIH, RC-Jammu
43. Sh. Suryansh Mandloi, Sc.B, NIH, CFMS-Patna (Oline)

Annexure-II

ENVIRONMENTAL HYDROLOGY DIVISION

Approved Work Programme for the Year 2022-23

SN	Study	Study Team	Duration/Status
	Sponsored Projects (Ongoing)		
1.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	Dr. R.P. Pandey, (PI). Er. Jagdeesh Patra, Dr. Rajesh Singh, Sh N. K. Bhatnagar,	3 years (12/17-12/20) Extension requested till 06/22 **Project cost:** Rs. 75.0 Lakh **Status:** In-progress
2.	Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanasi and surrounding area	Rajesh Singh (PI) R. P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 years (07/21-07/24) **Project cost:** Rs. 10.0 Lakh **Sponsored by**: BHU **Status:** In-progress
	Internal Study (Ongoing)		
3.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema	4 years (11/19-10/23) **Project cost:** Rs. 43.02 lakh **Status:** In-progress
4.	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar	Rajesh Singh (PI) J. V. Tyagi R. P. Pandey R.K. Nema Pradeep Kumar M. K. Sharma	2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal **Status:** In-progress
5.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Rajesh Singh (PI) R. K. Nema Sumant Kumar Pradeep Kumar M. K. Sharma	3 Years (07/21 – 06/24) **Project Cost:** 30.1 Lakhs **Sponsored by:** Internally **Status:** In-Progress
	Internal Study (New)		
6.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims of groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	M. K. Sharma (PI) RC, Kakinanda CGWB	2 years (04/22-03/24) **Sponsored by:** Internally **Status:** Proposed
	Consultancy Projects		
7.	Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh	J. V. Tyagi (Lead PI) R. P. Pandey (PI) P. Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural P. K. Singh Rajesh Singh	2.5 Years (03/20-08/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033 Crore **Status:** In-progress
8.	Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-I Power Station, NHPC	J.V. Tyagi R.P. Pandey Rajesh Singh (PI) M. K. Sharma	15 months (09/21-03/23) **Project Cost:** Rs. 3,24,500/- **Sponsored by:** CPWD Dehradun **Status:** In-progress

Proposed Training Programmes for 2022-23

SN	Topic	Duration	Place
1.	Water Quality: Concepts and Analysis under NHP for IRI officials (Coordinator: Dr. M. K. Sharma)	5 Days	Roorkee
2.	Estimation of Recharge for improving the Water Quality using MODFLOW & MT3D under NHP (Coordinator: Dr. M. K. Sharma)	5 Days	Roorkee
3.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days	Roorkee
4.	Water Quality Data Processing (Coordinator: Dr. Pradeep Kumar)	5 Days	Roorkee
5.	Leachate Transport in Groundwater under NHP-PDS (Coordinator: Ms. Anjali)	5 Days	Roorkee

GROUND WATER HYDROLOGY DIVISION

Approved Work Program for the year 2022-23

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Nitesh Patidar (PI), Gopal Krishan Anupma Sharma	2 years (08/20 – 07/22) *Status: In progress*	Internal Study
2. NIH/GWH/NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar (PI), S. Singh, R. Singh, G. Krishan, S. S. Rawat, M.K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel	3 years (04/22 – 03/25) Status: **New Study**	Internal Study
3. NIH/GWH/NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Gopal Krishan, Surjeet Singh, Sumant Kumar, Nidhi Kalyani	2 years (04/22 – 03/24) Status: **New Study**	Internal Study
4. NIH/GWH/NIH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	Nidhi Kalyani (PI), Anupma Sharma, Nitesh Patidar, Sumant Kumar	2 years (04/22 – 03/24) Status: **New Study**	Internal Study
Sponsored Projects				
5. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency)	Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao *BGS, UK:* Dan Lapworth Alan MacDonald Daren Goody	5 years (12/17-11/22) *Status: In progress*	BGS, UK
6. NIH/GW	Assessment of Impacts of Groundwater Salinity on Regional	Gopal Krishan (PI), Surjeet Singh, C. P.	4 years (12/17-07/22)	NHP under PDS

H/PDS/17-21	Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	Kumar (Retd.), *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav *Sehgal Foundation:* Lalit Mohan Sharma	*Status: In progress*	
7. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-07/22) *Status:* *In progress*	NHP under PDS
8. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) S. K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, P.K. Mishra, V. Singh, N. Patidar, N. Kalyani *Partners* Haryana Irr. & WR Dept., UPGW Dept., UYRB, CWC	4 years (04/18-01/24) *Status: In progress*	Special Project under "Centre of Excellence" (NHP)
9. NIH/GWH/DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (PI), Gopal Krishan, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 02/24) *Status: In progress*	DST
10. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator)	3 years (07/20 – 06/23) *Status: In progress*	Federal Min. of Education and Research, Germany
11. NIH/GWH/DST-SERB/21-24	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), MS Rao	3 years (04/21 – 03/24) *Status: In progress*	DST-SERB
12. NIH/GWH/APN/22	Capacity Development Program on Site Suitability Mapping for Managed Aquifer Recharge (MAR) under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools	Nitesh Patidar (PI), S. Singh, G. Krishan *IIT Roorkee(lead)*: Basant Yadav, Ashish Pandey, R D Singh, B. J. Deka *In-kind support:* KU, Japan: Yutaka Matsuno, PNU, South Korea: Sanghyun Jeong	10 months (01/22-10/22) *Status: New Study*	Asia-Pacific Network (APN)
Consultancy Projects				
1.	Groundwater Investigations of Rana Sugars Ltd. Buttar Seviyan Area of Amritsar District, Punjab	Surjeet Singh (PI)	6 months (01/22 – 06/22) *Status: In progress*	NIT, Jalandhar (Punjab)

HYDROLOGICAL INVESTIGATIONS DIVISION

Approved Work Programme for the year 2022-23

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Assessment of dissolved radon concentration in groundwater of Uttarakhand	Hukam Singh (PI), M Someshwar Rao Soban Singh Rawat Vipin Agarwal	1 ¾ years (04/21-12/22)	Continuing Study
2.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	SD Khobragade (PI) Dr. Vishal Singh Sudhir Kumar	3 years (04/22-03/25)	New Study
3.	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	Soban Singh Rawat, (PI) Sudhir Kumar, Santosh M. Pingale P K Mishra D. S. Bisht Rajesh Singh	3 years (04/22-03/25)	New Study
4.	Studies for selected springs of Tehri Garhwal region, Uttarakhand	MS Rao (PI) and Team		Chairman suggested that instead of Tehri Garhwal, a proposal on study of springs of North-East region may be formulated.
SPONSORED PROJECTS:				
1.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	M. Someshwar Rao (PI) Sudhir Kumar	3 Years (06/16 -12/22)	Continuing Study IAEA under CRP
2.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal	3 ½ year (01/18 – 06/22)	Continuing Study NHP (PDS)
3.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	M. S. Rao (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan	3 ½ years (01/18-06/22)	Continuing Study NHP (PDS)
4.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Suhas Khobragade (PI) Sudhir Kumar	3 years (01/18-06/22)	Continuing Study NHP (PDS)
5.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	Sudhir Kumar (PI) SM Pingale	2 years (06/19 – 09/22)	Continuing Study (IIT Bombay, Mumbai)
6.	Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining	S S Rawat (PI) Sudhir Kumar P G Jose Suman Gurjar	4 Years 17/08)– 0922/)	Continuing Study NHP (PDS)

S. N.	Project Title	Study Team	Duration	Status
	Local Water Demand in Ravi Catchment of Himachal Pradesh	D S Bisht		
7.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	S S Rawat (PI) P G Jose Suman Gurjar D S Bisht	3 years (01/19-09/22)	Continuing Study (NMHS)
8.	Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi M. K. Sharma Partner: CGWB (Delhi unit)	3½ years (11/19 – 06/23)	Continuing Study NHP (PDS) Transferred from EHD
9.	Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river	Sudhir Kumar, (Proj. Coordinator), M. K. Sharma, (PI) Suhas Khobragade Anjali Vishal Singh SM Pingale Nitesh Patidar Surjeet Singh	5 years (04/22-03/27)	DST

SURFACE WATER HYDROLOGY DIVISION

Approved Work Programme for the year 2022-23

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/19-23	Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP)	P C Nayak Y.R.Satyaji Rao A.K. Lohani B. Venkatesh A. R. S. Senthil Kumar T. Thomas	3 year (Sept 2019 to April 2023)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/ 20- 22	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.	J.P. Patra Rakesh Kumar Pankaj Mani Sunil Gurrapu	2 years (July 2020 to August 2022
2.NIH/SWHD/ 21-23	Uncertainty in rating curves and discharge estimation	Sanjay Kumar L. N. Thakural Sunil Gurrapu N.K. Bhatnagar J P Patra	2 Years (April 2021 to March 2023)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/ 22-22	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	A. K. Lohani, (PI) R. K. Jaiswal J. C. Patra P. C. Nayak Vishal Singh	Two Years April 2022 – March 2024
2.NIH/SWHD/ 22-23	Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A.	S.K. Singh	Six month (April 2022 to Sept. 2022)
3.NIH/SWHD/ 22-25	Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution	S.K. Singh	Six month (Oct. 2022 to March 2023)
4.NIH/SWHD/ 22-24	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak A. K. Lohani J. P. Patra Sunil Gurrapu T. Thomas Om Prakash Jatin Malhotra	3 Year (July 2022 to June 2025)
5.NIH/SWHD/ 22-25	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	L. N. Thakural M. K. Sharma R. K. Jaiswal J. P. Patra P. K. Mishra Nitesh Patidaar N. K. Bhatnagar Jatin Malhotra Anil Kumar Chhangani	2 Year (July 2022 to June 2024)
6.NIH/SWHD/ 22-24	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P.Patra A. K. Lohani Pankaj Mani P. C. Nayak Sanjay Kumar	3 Year (April 2022 to March 2025)
7.NIH/SWHD/ 22-25	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	Sunil Gurrapu Y R S Rao Nitesh Patidar R Venkat Raman	2 Year (April 2022 to March 2024)
8.NIH/SWHD/ 22-23	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade P.K. Mishra Sunil Gurrapu	3 years (April 2022 to March 2025)
9.NIH/SWHD/ 22-23	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar Jyoti Patil Rohit Sambare Charu Pandey	1.5 Year (May 2022 to Oct 2023)

WATER RESOURCES SYSTEMS DIVISION

Approved Work Programme for the year 2022-2023

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
Ongoing Sponsored/ Internal Studies				
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Sanjay K. Jain P K Singh M. Arora A K Lohani Vishal Singh	3 years (11/19-11/22)	NMHS-MoEF (143)
2.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Vishal Singh Sanjay K. Jain A P Dimri (JNU)	3 years (06/19-11/22)	NRDMS-DST (23.19)
3.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh P K Mishra P K Agarwal	2 years (08/20-07/22)	NHP (14.50)
4.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P K Mishra P K Singh Vishal Singh P K Agarwal	2 years (04/21-03/23)	NHP (9.00)
5.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh M K Nema P K Singh Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)	3 years (04/21-03/24)	NHP (25.00)
6.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	Vishal Singh Sanjay K. Jain Manohar Arora	2 years (08/20-07/22)	NIH (9.30)
7.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya	M K Nema Sanjay K Jain P K Mishra P K Agarwal	3 years (08/20-07/23)	NIH (10.22)
8.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora P K Mishra Vishal Singh	3 years (04/21-03/23)	NIH
New Internal/ Sponsored Studies				
1.	Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin	M K Nema P K Mishra	2 years (04/22-03/24)	NIH
2.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	M K Nema Sanjay K Jain P. K. Mishra Praveen Thakur (IIRS)	3 years (04/22-03/25)	IIRS, Dehradun (30.91)
3.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	P K Singh; Vishal Singh Sanjay K Jain	3 years (04/22-03/25)	WRD, Karnataka (54.0)

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

Approved Work Program for the year 2022-23

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	NIH	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sep 2020- Feb 2023	On-going
2	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Sep 2020- Aug 2023	On-going
3	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	NIH	A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Sep 2020- Aug 2022	On-going
4	Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun	NIH	Omkar Singh (PI) V.C. Goyal, Rajesh Singh (Co-PI), Jyoti Patil, Rohit Sambare, N.R. Allaka; Team from SRHU-HIHT, Dehradun	April 2022- Mar 2024	New Study
Sponsored Projects					
1	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI)	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	On-going

Proposed Training/Webinar/Outreach Activities of RMOD (2022-23)

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Brainstorming session on ‘Water Security in a Changing Environment- Focus on Indian Himalayan Region (IHR)’, during 16th Uttarakhand Science and Technology Congress	June 2022	UCOST, Dehradun	Conference participants	V. C. Goyal, J P Patil, Amrendra Bhushan

2	5-days training on 'Life Cycle Approach for Rejuvenation of Ponds and Lakes using Nature-Based Solutions' sponsored by National Water Mission (4Nos)	April 2022 May 2022 June 2022 July 2022	Bhopal Belgaum Kakinada Roorkee	R&D Institutes/ University/ Govt. Organizations	Bhopal: T Thomas Belgavi: B Venkatesh Kakinada: YRS Rao Roorkee: J P Patil, Omkar Singh, Rohit Sambhare
3	Training on GEM	June 2022	NIH Roorkee	Admn and finance staff of NIH	A. R. Senthil kumar Omkar Singh
4	Webinar on ecohydrological functioning of wetlands	Jul 2022	NIH Roorkee	Students and researchers	Rohit Sambare V C Goyal
5	Stakeholders workshop for Upper Dhasan Basin water resources assessment	May 2022	Bhopal	CWC, CGWB, State depts (Irrigation, WRD, Agril etc)	J P Patil, T Thomas, P K Mishra, Rohit Sambhare
6	Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands	Jul 2022	NIH Roorkee	R&D Institutes/University/Govt. Organizations	NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst
7	Five-day training program on "Hydrology of water bodies and their development under climatic uncertainty"	Jun/Jul 2022	NIH Roorkee	Engineers in Irrigation/PHE/SWC departments	A. R. Senthil kumar, Rohit Sambare, Santosh M Pingale, N R Allaka
8	E-course on Urban hydrology	June 2022	NIH, Roorkee NIUA, Delhi	Researchers, academicians, scholars	NIH: V C. Goyal, J. P. Patil NIUA: Victor Shinde
9	Awareness Programme for School Children	July-Sep 2022	3 schools in Roorkee/ nearby	School Children	Digambar Singh, Omkar Singh, A. R. Senthil kumar, Rajesh Agarwal, N R Allaka

Other Outreach Activities:

S.N.	**Activity**
1	• Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi • River Walk of Solani River • Short video on Hydrology for People @district level • Short video on vulnerability assessment under Hydrology for People series
2	• Coordination of 75 planned Activities at HQ & RCs under Azadi Ka Amrut Mahotsav @ India 75 • Organizing activities as per mandate of Division under Azadi Ka Amrut Mahotsav @ India 75 • Compendium of NIH activities on the activities under Azadi Ka Amrut Mahotsav @ India 75
3	• Any other Outreach activity on demand/assigned

HARD ROCK REGIONAL CENTRE, BELAGAVI

Approved Work Program for the year 2022-23

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Monitoring and Evaluation of Ground Water Quality of Belagavi City, Karnataka, India	Varadarajan N (PI) Chandra Kumar S. Abhilash R	2 year (6/22 to 5/24)	New Study
SPONSORED PROJECTS:				
1.	Groundwater Model Development in Micro Basin of Hard Rock in Krishna And Godavari River Basins of Telangana	B Venkatesh (PI) M K Jose Sudhir Kumar Abhilash R & Officials form TSGWD	*3 years* (Sept 2019 –Aug 2022 Extended upto August 2023	Special Studies under NHP
2.	Impact of Sand Mining On Groundwater Regime in Parts of Manjira River Basin, Telangana State	M K Jose (PI) B Venkatesh Chandramohan T. Abhilash R and Officials form TSGWD	*2 years* Sept 2021 – Aug 2023	Special Studies under NHP
3	Comprehensive Assessment of Water Availability, Use and Issues for Goa State	B Venkatesh, Chandramohan T. Abhilash R and Officials of WRD Goa	2 years (01/22 to 12/23)	Special Studies under NHP

WESTERN HIMALAYAN REGIONAL CENTRE, JAMMU

Approved Work program for the year 2022-23

S. No.	Title of Study	Team	Duration	Remarks
Internal Studies				
1.	Estimation of changes in snow cover and climate-cryosphere interaction in Upper Chenab river basin	P. G. Jose D. S. Bisht	02 Years 07 months (Aug. 2020 – Mar. 2023)	Ongoing, Extn. up to March 2023
2.	Mass balance of Phuche and Khardung glaciers, Ladakh with implications for downstream water availability under changing climate.	P. G. Jose D. S. Bisht D. Khurana	03 Years (July 2021-June 2024)	Ongoing
3.	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan basin	R. V. Kale D. Khurana	03 Years (Sept. 2021-July 2024)	Ongoing
4.	Early signatures of 21st Century on snow cover dynamics in Zanskar river basin, Ladakh	D. S. Bisht P. G. Jose	02 Years (July 2021 - June 2023)	Ongoing
5.	Comparative analysis of fine-scale satellite & reanalysis precipitation products in Upper Ganga Basin using Multi-Criterion Decision-Making	D. S. Bisht M. K. Goel	01 Year (June 2022 – May 2023)	New Study
Externally funded R & D Studies				
1.	Web-enabled inventory of natural water springs of Tawi river catchment of J&K State of India for vulnerability analysis and developing adaptive measures for sustaining Tawi river	S. S. Rawat P. G. Jose S. Gurjar D. S. galkate	03 years (April March 2019 to 2022)	Ongoing study funded by NMHS (2 Co-PIs at WHRC)
2.	Operational coastal flood management through short-to-medium range flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI)	03 years (July, 2020 – June, 2023)	Ongoing study funded under STARS by MHRD, GoI.
3.	Permafrost mapping and characterization of Western Himalayan Region	P. G. Jose A.P. Dimri (JNU) G. Jeelani (KU) V. Agnihotri (GBPNIHESD)	03 years (Aug 2019-Aug 2022)	Ongoing study funded under NMHS. PI vide letter dtd.10.2.2022

CENTRAL INDIA HYDROLOGY REGIONAL CENTRE, BHOPAL

Approved Work Program for the year 2022-23

SN	Title of Project/Study	Study Team	Duration	Status & Comments/ suggestions	Funding
Internal Studies					
1.	An experimental assessment of low-cost Auger Hole Technique for accelerating groundwater recharge	**NIH** R.V. Galkate R.K. Jaiswal **MP-WALMI** Vivek Bhatt	2 years (Sept 2020 – August 2022)	Ongoing In-progress in collaboration with WALMI Bhopal	Internal
2.	Re-assessment of evapotranspiration (*ETo*) estimation for irrigation planning in Madhya Pradesh	**NIH** R.V. Galkate R.K. Jaiswal A.K. Lohani Shashi Indwar **MP-WRD, Bhopal** Deepak Satpute Sayyam Jhanjari Sameer Soni	3 years (Nov 2021 – Oct 2024)	Ongoing In-progress in collaboration with BODHI, MPWRD Bhopal	Internal
3.	Water Availability Assessment for Project Formulation in Sub Basins of Ganga River in Madhya Pradesh	**NIH** R K Jaiswal, Ravi Galkate A K Lohani **MP-WRD, Bhopal** B Baghel	3 years (Nov 2021 – Oct 2024)	On-going	Internal
4.	Development of Reservoir Operation Plan under Climate Change scenarios for Kolar reservoir	**NIH** Shashi Indwar T. Thomas R. K. Jaiswal R.V. Galkate **MP-WRD, Bhopal** C.E, Hoshangaba, S.E Kolar E.E Kolar.	3 years (Oct 2021 – Sept 2024)	On-going	Internal
Sponsored Projects					
5.	Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh	**NIH** T. Thomas, B. Venkatesh R.V. Galkate Shashi Indwar R. K. Jaiswal P. C. Nayak Surjeet Singh **MP-WRD, Bhopal** Director Hydromet Mahesh Paliwal B. Baghel.	4 years (Dec 2017- July 2022)	Ongoing	PDS under NHP
6.	Integrated Assessment of the Impacts of Climate Change and Land-use Change on the Hydrology of	**NIH** T. Thomas, B. Venkatesh P. C. Nayak	5 years (Feb 2018 – Sep 2023)	Ongoing	Special PDS under NHP

	the Narmada basin through Hydrological Modelling Approaches	Surjeet Singh Shashi Indwar **MP-WRD, Bhopal** Director Hydromet Mahesh Paliwal, B. Baghel.			
7.	Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Sanjay Sagar Project in Madhya Pradesh	**NIH** R K Jaiswal Ravi Galkate T Thomas Shashi Indwar A K Lohani Sudheer Kumar Surjeet Singh **MP-WRD, Bhopal** Director, Hydromet, SE, GW circle, Database Admin, SE, EE, and AEs of Bah Project	4 years (Apr 2019 – Sept 2023)	Ongoing	PDS under NHP
8.	Development of Decision Tool for Efficient Utilization of Water Resource in Parbati Canal Irrigation Project of Rajasthan:	**NIH** R K Jaiswal, Ravi Galkate Shashi Indwar A K Lohani **WRD Rajasthan** Shailendra Kumar Sanjay Agrawal C B Garg	3 years (Apr 2019- March 2022) *(Granted Extension up to Sept 2022 by NPMU due to Corona reason)*	On-going	PDS under NHP
9.	Integrated reservoir operation studies for Mahanadi reservoir project complex in Chhattisgarh: SP-56/2021-22/NIH (CIHRC)	**NIH** R K Jaiswal, Ravi Galkate Shashi Indwar A. K. Lohani M. K. Goel, Vishal Singh Sumit Saini Dipti Rani **WRD Chhattisgarh** A. Verma, J. K. Das, V. K. Dubey A. Gupta, P. Awadhiya, **IGKV Raipur** S. Chandinah	2 years (Apr 2022-Mar 2024)	New Study	SP under NHP

DELTAIC REGIONAL CENTRE, KAKINADA

Approved Work Programme for the year 2022–23

S.No.	Title of the Project	Team	Duration (Start Date and End Date)	Funding
I. Internal Project (ongoing)				
1.	Identification of Recharge and Discharge areas of Palar river basin in Tamilnadu	V.S. Jeyakanthan (PI) J.V.Tyagi Sudhir Kumar Y.R.Satyaji Rao R.Venkata Ramana	2 years 09/21 - 03/23	Internal Funding (NIH)
Internal Study (New project)				
2	Impact assessment of backwater through drains, creeks and river mouths on groundwater salinity in the Godavari Delta, Andhra Pradesh	Y.R.Satyaji Rao (PI) Sudhir Kumar V.S.Jeyakanthan R.Venkata Ramana	2 years 08/22 - 08/24	Internal Funding (NIH)
II. Sponsored Projects (Ongoing)				
3	Urban hydrological studies of critical pilot area using of hydrological instruments in the Greater Hyderabad Municipal Corporation (GHMC) area Hyderabad	R. Venkata Ramana (PI) Y.R.Satyaji Rao V.S.Jeyakanthan T.Vijay	3 Years 01/20-04/23	NHP (PDS) (LA: I & CAD, Govt. of Telangana) TEL-6_2017_2018
4.	High Performance Advanced Septic System for Villages and Roadside Restaurants	Y.R. Satyaji Rao (PI) T.Vijay	3 Years 04/18 – 12/22	IC – IMPACT Canada
III. Sponsored Project (New Project)				
5.	Quantification of SGD and its quality flux along the north coastal Andhra Pradesh	Y.R. Satyaji Rao (PI) Sudhir Kumar, S.M Pingale, M.K.Sharma R.Venkata Ramana	3 years (07/22 -07/25)	Funded by NCESS, MoES

NORTH EASTERN REGIONAL CENTRE, GUWAHATI

Approved Work Programme for the year 2022-23

Sl. No.	Title	Study Group	Duration (Month/Year)	Study Type	Remarks
Internal Projects (On-going)					
1.	Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin	*Gulshan Tirkey, S. K. Sharma P. Mani	#3 years (4/18 to 3/21)	Internal	*PI to be Dr. S.K. Sharma #Study extended till 3/23
2.	Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya	*G. Tirkey, S. K. Sharma A. K. Lohani	#2 years (9/20-8/22)	Internal	*PI to be Dr. S.K. Sharma #Study extended till 3/23
Sponsored Projects (On-going)					
3.	River basin planning studies in Teesta basin up to confluence with Rangit River in Sikkim	S. Barman M.K. Goel A.K. Lohani D.S. Rathore Deepti Raani W.R. Singh	3 years (3/19 to 2/22)	Sponsored under NHP	On-going
4.	Study on Behaviors of Flooding and Unexpected Drought like Situations in Garo Hills District of Meghalaya	S. K. Sharma R.P. Pandey GulshanTirkey S.Barman W.R. Singh	3 years (10/19 to 9/22)	Sponsored under NHP	On-going
5.	A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World	S. Barman, R.K. Bhattacharya M.K. Dutta, W.R. Singh	3 Years (4/21-3/24)	Sponsored under DST-SERB Power grant	On-going
Internal Projects (New)					
6.	Impact of Climate Change on Flood Inundation in Beki River Basin	S.K. Sharma, S. Barman, W.R. Singh, S.V. Vijaya Kumar	1 years (7/22-6/23)	Internal	New-Study
7.	Drought characterization and vulnerability assessment in Assam	W.R. Singh, S. Barman, S.K. Sharma, S.V. Vijaya Kumar, A.K. Lohani	2 years (7/22-6/24)	Internal	New-Study

CENTRE FOR FLOOD MANAGEMENT STUDIES, PATNA

Approved Work Programme for the year 2022-2023

Sl	Title	Study Team	Duration
Internal Studies			
1	Integrated Flood Management Plan for a stretch of Burhi Gandak River from Sikanderpur to Rosera	B Chakravorty(PI), Pankaj Mani and NG Pandey, Ex. Scientist	3 years (04/20-09/22)
2	Design flood estimation for small structures in the south Bihar area.	Pankaj Mani (PI), J. P. Patra B Chakravorty, I C Thakur, Director WALMI	2 years (04/21-11/22)
Sponsored Study (PDS/NHP)			
1.	Modeling and management of erosion and sedimentation processes in a reach of Gandak river using morphodynamic modeling	Pankaj Mani(PI) J. P. Patra B. Chakravorty & WRD Bihar	3 years (05/21-04/24)
New Study			
1.	Study of flood mitigation measures in Mahav nala using mathematical modelling study (New study)	Pankaj Mani (PI), J. P. Patra B Chakravorty with support from UP Irrigation Department and Forest Department (Maharajganj)	1 years (04/22-03/23)

APPENDIX – 77.6.1

WORK PROGRAMME OF THE DIVISIONS AT THE H.Q. AND RC's/CFMS OF THE INSTITUTE FOR THE YEAR 2022-2023 & 2023-24

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. R P Pandey	Scientist G & Head
2	Dr. M K Sharma	Scientist F
3	Dr. Pradeep Kumar	Scientist E
4	Dr. Rajesh Singh	Scientist D
5	Dr. Vinay Kumar Tyagi	Scientist D
6	Dr. Kalzang Chhoden	Scientist C
7	Dr. Shakti Suryavanshi	Scientist C
8	Dr. Shailendra Kumar Kumre	Scientist B
9	Smt. Babita Sharma	SRA
10	Smt. Bina Prasad	SRA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हि ष्ठा मयोभुवः

APPROVED WORK PROGRAMME FOR THE YEAR 2022-23

S. N.	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	Dr. R. P. Pandey, (PI) Er. Jagdeesh Patra, Dr. Rajesh Singh Sh. N. K. Bhatnagar	3 Years (12/17-03/22) Further Extension till may 2023 **Project Cost**: 75 Lakh Sponsored by: NHP Status: In-progress
2.	Anaerobic Co-digestion of Thermochemically Pretreated Organic Fraction of Municipal Solid Waste and Sewage Sludge: Effect on Process Performance and Microbial Community Development	Dr. Vinay Kumar Tyagi, Sc, 'D' (PI)	5 Years (2018-2023) **Project Cost**: 106 Lakhs **Sponsored by**: DBT **Status**: In-progress
Collaborative Projects (Ongoing)			
3.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	Dr. Rajesh Singh (PI) Dr. R.P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 Years (07/21-06/24) **Sponsored by**: BHU **Status**: In-progress
4	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	Dr. Vinay Kumar Tyagi, Sc, 'D' (Co-PI) Dr. A.A.Kazmi (PI, IITR)	02 Years (01/22-12/23) **Sponsored by**: Central Pollution Control Board (CPCB)-NMCG
5	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	Dr. Vinay Kumar Tyagi, Sc, 'D' (Co-PI) Dr. A.A.Kazmi (PI, IITR)	4 Years (03/20-02/24) **Sponsored by**: Department of Science & Technology (DST)
Internal Study (Ongoing)			
6.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	Dr. M. K. Sharma, Sc. F (PI) Dr. Suhas Khobragade, Sc. 'G' Dr. Rajesh Singh, Sc. 'D'	2 Years (04/22-03-24) **Status:** In-progress
7.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Dr. Rajesh Singh, Sc. D (PI) Dr. R. P. Pandey, Sc. G Dr. Sumant Kumar, Sc. D, Dr. Pradeep Kumar, Sc. D Dr. M. K. Sharma, Sc. F Dr. V. K. Tyagi, Sc, D Dr. Kalzang Chhoden, Sc. C	3 Years (07/21-06/24) **Status:** In-progress
8.	Simulation of Non-Point Source Pollution Processes in Song River	Dr. Pradeep Kumar, Sc. D (PI) Dr. M.K. Sharma, Sc. F Dr. Rajesh Singh, Sc. D Er. R.K. Nema, Sc. B	4 Years (11/19-10/23) **Status:** In-progress
Internal Study (New)			
9.	Hydrological Studies for the Conservation of Rewalsar Lake	Dr. Kalzang Chhoden, Sc. C, (PI) Dr. Rajesh Singh, Sc. D Dr. R. P. Pandey, Sc. G Dr. Pradeep Kumar, Sc. D Dr. Vinay Kumar Tyagi, Sc. D	3 Years (12/22-11/25) **Status:** Proposed

		Er. Omkar Singh, Sc. G Dr. Shuhas Khobragade, Sc. G Dr. D.S. Malik, Professor, GKU, Haridwar	
10.	Comprehensive evaluation of disinfection units of STPs in Ganga basin: Occurrence and control the formation of emerging oxidation precursors	Dr. Vinay Kumar Tyagi, Sc. D (PI) Dr. Rajesh Singh, Sc. D Dr. Mukesh K. Sharma, Sc. F Dr. Pradeep Kumar, Sc. D Er. J. P. Patra, Sc. D Dr. Kalzang Chhoden, Sc. C Dr. R.P.Pandey, Sc. G	3 Years **Status:** Proposed
Consultancy Projects (Completed)			
11.	Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh	Dr. J.V. Tyagi (Lead PI) Dr. R.P. Pandey (PI) Dr. P. Kumar (Co-PI) Dr. T. Thomas Dr. L.N. Thakural Dr. P.K. Singh	2.5 Years (03/20-08/22) **Sponsored by;** ICFRE **Project Cost:** Rs. 110.33 Lakhs **Status:** Completed
12.	Site Selection for Intake Well in Alaknanda River near Srinagar for Marhi Chauras Pumping Peyjal Yojna	Dr. R.P. Pandey, Sc 'G' & PI Dr. Pradeep Kumar, Sc 'D' Dr. Rajesh Singh, Sc. 'D' Dr. Vinay Tyagi, Sc 'D'	1 Months (11/22-12/22) **Sponsored by**: Uttarakhand Peyjal Nigam **Project Cost:** Rs. 1.80 Lakh **Status:** Completed
13.	Site Selection for Intake Well in Ganga River Bharpoor Pumping Peyjal Yojna Phase-II	Dr. R.P. Pandey, Sc 'G' & PI Dr. Pradeep Kumar, Sc 'D' Dr. Rajesh Singh, Sc. 'D' Dr. Vinay Tyagi, Sc 'D'	1 Months (12/22-01/23) **Sponsored by:** Uttarakhand Peyjal Nigam **Project Cost:** Rs. 1.80 Lakh **Status:** Completed
Consultancy Projects (On-going)			
14.	Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-1 Power Station, NHPC	Dr. J V Tyagi Dr. R.P. Pandey, Sc 'G' Dr. Rajesh Singh, Sc 'D' (PI) Dr. M.K. Sharma, Sc. 'F' Sh. Rakesh Goyal, Tech. Gr. I	15 Months (12/21-03/23) **Sponsored by:** Innovante Water Soluation Pvt. Ltd. Roorkee **Cost**: Rs. 3.245 Lakh **Status:** On-going
15.	Performance evaluation of Nano Catalytical Instant Water Converter (NCIWC) equipment for water and wastewater treatment	Dr. J.V. Tyagi Dr. R.P. Pandey, Sc 'G' Dr. Rajesh Singh, Sc. 'D' & PI Dr. Sumant Kumar, Sc. 'D' Dr. Vinay Tyagi, Sc. 'D' Dr. M.K. Sharma, Sc. 'F' Dr. Pradeep Kumar, Sc. 'D'	06 Months (05/22-11/22) Further Extension Requested **Sponsored by:** Envirogreen Minetech India Pvt. Ltd., Indore M.P. **Cost**: Rs. 5.90 Lakhs **Status:** On-going
Consultancy Projects (New)			
16.	Water Quality Studies for Tehri Reservoir Tehri HPP (4x250MW)	Dr. Sudhir Kumar, Director Dr. R.P. Pandey, Sc, 'G' Dr. M.K. Sharma, Sc, 'F' (PI) Dr. Pradeep Kumar, Sc, 'D' Dr. Rajesh Singh, Sc, 'D' Mrs. Babita Sharma, SRA	2 Years (02/23-01/25) **Sponsored by:** THDC, India Limited **Cost:** Rs. 6.91 Lakh **Status:** Proposed

		Mrs. Been Prasad, SRA	
17.	Technical Evaluation of Infiltration Well of Dadua-Bhandali Mineral Water Pumping Scheme on Alaknanda River for Feasible Options to Maintain the Supply	Dr. R.P. Pandey, Sc, 'G' (PI) Dr. Pradeep Kumar, Sc, 'D' Dr. Rajesh Singh, Sc, 'D' Dr. V. K. Tyagi, Sc. 'D'	02 Weeks (02/23-03/23) **Sponsored by:** Uttarakhand Peyjal Nigam **Cost:** Rs.1.62 Lakh **Status:** On-going

PUBLICATIONS

International Journal	National Journal	International Conference	National Conference	Book	Book Chapter	Total
23	-	19	02	02	08	**54**

- **International Journals (23 Nos.):**

1. Ali Mohammad Rahmani, Vinay Kumar Tyagi, Neelam Gunjyal, A. A. Kazmi, Chandra Shekhar P. Ojha, Konstantinos Moustakas (2022) Hydrothermal and thermal-alkali pretreatments of wheat straw: co-digestion, substrate solubilization, biogas yield and kinetic study. Environmental Research, 216 (1), 114436.
2. Ali Mohammad Rahmani; Vinay Kumar Tyagi; Banafsha Ahmed; A. A. Kazmi; Chandra Shekhar P. Ojha; Rajesh Singh (2022) Critical insights into anaerobic co-digestion of wheat straw with food waste and cattle manure: Synergistic effects on biogas yield and kinetic modeling. Environmental Research, 212, 113382.
3. Ankur Rajpal, Akansha Bhatia, Nilesh Tomar, A A Kazmi, Chandra Shekhar P Ojha, Vinay Kumar Tyagi (2022) Insight into a novel post-anoxic integrated biofilm process for wastewater treatment and reclamation. Journal of Water Process Engineering, 49, 102957 [IF: 5.485].
4. Anwar Khursheed; Muntjeer Ali, Faris Mohammad A. Munshi, Abdulrhman Fahmi Alali, Mohab Amin Kamal, Abdulaziz Ibrahim Almohana, Omar Alrehaili, Rubia Z. Gaur, Vinay Kumar Tyagi, Abid A. Khan, Gaurav Goel (2022) Enhanced Combined Assimilative and Bound Phosphorus Uptake in Concurrence with Nitrate Removal in Pre-Anoxic Cyclic Sequencing Batch Reactor. Environmental Technology and Innovation, 28, 102909.
5. Balasundaram, G., Vidyarthi, P.K., Gahlot, P., Arora, P., Kumar, V., Kumar, M., Kazmi, A.A., Tyagi, V.K. (2022) Energy feasibility and life cycle assessment of sludge pretreatment methods for advanced anaerobic digestion. Bioresource Technology, 357, 127345.
6. Ganesh Sude, Ankur Rajpal, Vinay Kumar Tyagi, Kapil Sharma, Pravin Kumar Mutiyar, B.K. Panday, R.P. Pandey, Absar Ahmad Kazmi (2023) Evaluation of sludge quality in Indian sewage treatment plants to develop quality control indices. Environmental Science and Pollution Research (Accepted). https://doi.org/10.1007/s11356-023-25320-1.
7. Khursheed, Anwar; Munshi, Faris Mohammad A; Almohana, Abdulaziz Ibrahim; Alali; Kamal, Mohab Amin; Alam; Shamshad, Alrehaili, Omar; Islam, Dar Tafazul; Kumar, Manish; Varjani, Sunita; Kazmi, AA, Tyagi, Vinay Kumar (2023) Resolution of Conflict of Reduced Sludge Production with EBPR by Coupling OSA to A^2/O Process in a Pilot Scale SBR. Chemosphere. 318, 137-345.
8. Kumar, A., Tripathi, V. K., Kumar, P. and Rakshit, A. (2022). Assessment of hydrologic impact on flow regime due to dam inception using IHA framework. Environmental Science and Pollution Research. [IF: 5.053]
9. Malhotra, M., Aboudi, K., Pisharody, L., Singh, A., Banu, R., Bhatia, S.K., Varjani, S., Kumar, S., González-Fernández, C., Kumar, S., Singh, R., Tyagi, Vinay Kumar (2022) Biorefinery of anaerobic digestate in a circular bioeconomy: Opportunities, challenges and perspectives. Renewable and Sustainable Energy Reviews, 166, 112642.
10. Monika Yadav, Venkatesh Balan, Sunita Varjani, Vinay Kumar Tyagi, Gaurav Chaudhary, Nidhi Pareek, Vivekanand (2022) Multidisciplinary Pretreatment Approaches to Improve the Bio-methane Production from Lignocellulosic Biomass. BioEnergy Research. [IF: 3.852].
11. Pallavi Gahlot; Vinay Kumar Tyagi, Gowtham Balasundaram; A.E. Atabani; Surinder Suthar; A.A. Kazmi; Libor Štěpanec; Dagmar Juchelková; Arvind Kumar (2022) Principles and

potential of Thermal hydrolysis of sewage sludge to enhance anaerobic digestion. Environmental Research. [IF: 8.431]

12. Pandey, RP (2021) Hydrological Drought in India – An institutionalized systemic hydrological management challenge (Case study 2). A policy-note contribution in FAO publication entitled "*A rapid review of drought risk mitigation measures – Integrated drought management*" (Author: Caroline King-Okumu; Eds: Maher Salman, FAO-UN and Daniel Tsegai, UNCCD). Rome, FAO, pp. 128-131, https://doi.org/10.4060/cb7085en.
13. Phurba Tamang, Vinay Kumar Tyagi, Neelam Gunjyal, Ali Mohammad Rahmani, Rajesh Singh, Pradeep Kumar, Banafsha Ahmed, Pooja Tyagi, Rajesh Banu, Sunita Varjani, A.A. Kazmi (2023) Free nitrous acid (FNA) pretreatment enhances biomethanation of lignocellulosic agro- waste (Wheat Straw). Energy, 264, 126249.
14. Preethi, J. Rajesh Banu, Gopalakrishnakumar, Vinay Kumar Tyagi, Amit Kumar Bajhaiya, Poornachandar Gugulothu, M. Gunasekaran (2022) Biohydrogen production from waste activated sludge through thermochemical mechanical pretreatment, Bioresource Technology, 358, 127301.
15. R. Yukesh Kannah, M. Dinesh Kumar, S. Kavitha, J. Rajesh Banu, Vinay Kumar Tyagi, P.Rajaguru, Gopalakrishnan Kumar (2022) Production and recovery of polyhydroxyalkanoates (PHA) from waste streams – A review, Bioresource Technology, 366, 128203.
16. Rajesh Banu, S. Kavitha, Yukesh Kannah Ravi, Jayakodi J, Gopalakrishnan Kumar, Vinay Kumar Tyagi and Shashi Kant Bhatia (2023) Effect of surfactant addition on disperser disintegration of water hyacinth: a new insight to overcome the inhibitory effect of lignin on methanogenesis energy and economic aspects. Sustainable Energy & Fuels. https://doi.org/10.1039/D2SE01194H.
17. Sandeep K. Malyan, Omkar Singh, Amit Kumar, Gagan Anand, Rajesh Singh, Sandeep Singh, Zhiguo Yu, Jhlasesh Kumar, Ram K. Fagodiya, Amit Kumar (2022) Greenhouse Gases Trade-Off from Ponds: An Overview of Emission Process and Their Driving Factors , https://doi.org /10.3390/w14060970.
18. Sharma, M. K., Kumar, Pradeep, Bhanot, Kunarika and Prajapati, Parul, Wadhwa, Udita, Tomar, Garima, Goyal, Rakesh, Prasad, Beena and Sharma, Babita (2022) Study of hydrochemical and geochemical characteristics and solute fluxes in Upper Ganga Basin, India, J. Asian Earth Sciences: X, https://doi.org/10.1016/j.jaesx.2022.100108 (IF: 3.374).
19. Shashi Kant Bhatia, Vishal Ahuja, Neha Chandel, Ranjit Gurav, Ravi Kant Bhatia, Muthuswamy Govarthanan, Vinay Kumar Tyagi, Vinod Kumar, Arivalagan Pugazendhi, J Rajesh Banu, Yung-Hun Yang (2022) Advances in algal biomass pretreatment and its valorisation into biochemical and bioenergy by the microbial processes. Bioresource Technology, 358, 127437 [IF: 9.642].
20. Singh S., Rawat M., Malyan S. K., Singh R., Tyagi V. K., Singh K., Kashyap S., Kumar S., Sharma M., Pandey B. K., Pandey R. P. (2023). Global distribution of pesticides in freshwater resources and their remediation approaches. Environmental Research (Accepted) (I.F.: 8.431).
21. V.C. Goyal, Omkar Singh, Rajesh Singh, Kalzang Chhoden, Sandeep K. Malayn (2022) Appraisal of heavy metal pollution in the water resources of Western Uttar Pradesh, India and associated risks, https://doi.org/10.1016/j.envadv.2022.100230.
22. Vivek Narisetty, Maureen Chiebonam Okibe, K. Amulya, Esther Oreoluwa Jokodola, Frederic Coulon, Vinay Kumar Tyagi, Piet N.L. Lens, Binod Parameswaran, Vinod Kumar (2022) Technological advancements in valorization of second generation (2G) feedstocks for bio-based succinic acid production. Bioresource Technology, [IF: 9.642].
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- **National Journals: NIL**
- **International Conferences (19 nos.) :**

1. K. Singh, R. Singh, G. Pandey, 2022. Hydrogeochemistry, solute source identification, and health risk assessment of groundwater of cancer prone region in India. Water Supply (In press) https://doi.org/10.2166/ws.2022.435 (IF: 1.768).
2. S. Singh, C. Maithani, S. K. Malyan, A. Soti, N. M. Kulshreshtha, R. Singh, U. Brighu, A. B. Gupta, J. Kumar, S. Yadav, O. Singh, V. C. Goyal, 2022. Comparative performance and metagenomic analysis of deep and shallow cells of a full-scale HFCW having sequentially decreasing depths reveals vast enhancement potential. In International Conference on Biotechnology for Sustainable Bioresources and Bioeconomy (BSBB-2022) organized by the Indian Instit.
3. Balasundaram, G., Gahlot, P., Tyagi, V.K., Kazmi, A.A. (2022) "Coupled Steam explosion with anaerobic digestion to produce class A biosolids in municipal wastewater treatment plants in India: 7th India Water Week conclave,1st -5th November 2022, Greater Noida, India Oct 29-31, 2022 (ORAL, Second Prize)
4. Balasundaram, G., Gahlot, P., Tyagi, V.K., Kazmi, A.A. (2022) "Fostering solubilisation and biodegradation of sewage sludge using steam explosion pretreatment: 7th International conference on opportunities and challenges in agricultural, environmental and biosciences for global development (OCAEBGD), Oct 29-31, 2022 Goa, India (ORAL)
5. Balasundaram, G., Gahlot, P., Tyagi, V.K., Kazmi, A.A. (2022) "Investigating the effects of pilot scale thermal pretreatment facility on class A biosolids production from sewage sludge". In : 13th International symposium on southeast asian water environment , 13th-15th December 2022, Bangkok, Thailand (ORAL).
6. Bhanot, Kunarika, Sharma, M. K. and Kaushik, R. D. (2023) Evaluation of the water quality of River Alaknanda, a tributary of River Ganga using Water Quality Index, Online International Conference on Environment, Water, Agriculture, Sustainability and Health (EWASH-2022): Strategizing A Greener Future & 4th Annual Meet of STE, Organized by Hindu College, University of Delhi, Delhi and Save The Environment, 12-13 January 2013, Abstract Book & Souvenir, Page 24. (Best Paper Award)
7. Gahlot, P, Balasundaram, G, Tyagi, V.K., Kazmi, A.A. (2022) "Metagenomic analysis of sewage sludge microbiota and their potential to metabolize micropollutants". In: 13th International symposium on southeast Asian water environment, 13th-15th December 2022, Bangkok, Thailand (ORAL).
8. Gupta, A., Jain, M.K., and Pandey, R.P. Comparison between Gridded and Point Datasets for Drought Analysis in the Semi-arid Basin of Peninsular India. Abstract ID: 1057986, Paper No. H45F-07. Presented at AGU Fall Meeting, Chicago IL, USA, December 12 – 16, 2022.
9. Kalzang Chhoden, Chhavi K. Manchanda, Impact Assessment of Ponds on groundwater quality in vicinity area of District Ropar, Punjab, Challenges of Sustainability of Ground Water Resources, Proceeding in 7th India Water Week, 2022.
10. Kaptan Singh, Rajesh Singh, Govind Pandey, Sandeep Singh, Sandeep K Malyan, 2022. Scenario of Hydrochemistry, Health risk, and Solute Source in Groundwater of Bathinda District, Punjab. In India Water Week (IWW - 2022) organized by NWDA, MoJS, GOI during Nov. 01-05, 2022.
11. Kaptan Singh, Rajesh Singh, Govind Pandey, Sandeep Singh, Sandeep K Malyan, 2022. Assessment of Lead in groundwater, health risk and leaching behavior from sediments of Mansa district. In International Groundwater Conference (IGWC 2022) organized by Department of Hydrology, IIT Roorkee during Nov. 02-04, 2022.
12. Kumar, Mohit, Sharma, M. K. and Malik, D. S. (2023) Numerical groundwater flow and sulphate transport modelling in gypsum enriched aquifer of Bemetara district, Chhattisgarh state, India, Online International Conference on Environment, Water, Agriculture, Sustainability and Health (EWASH-2022): Strategizing A Greener Future & 4th Annual Meet of STE, Organized by Hindu College, University of Delhi, Delhi and Save The Environment, 12-13 January 2013, Abstract Book & Souvenir, Page 29.
13. Sandeep K Malyan, Rajesh Singh, Sandeep Singh, Arti Bhatia, 2022. Assessment of Greenhouse gas emissions from a Horizontal Subsurface Flow Constructed wetland in Roorkee, India. In India Water Week (IWW - 2022) organized by NWDA, MoJS, GOI during Nov. 01-05, 2022.

14. Sandeep Singh, Sandeep K Malyan, Kaptan Singh, Rajesh Singh, 2022. Evaluation of Metals, Pesticides, PAHs and PCBs in groundwater of Malwa Region of Punjab, India. India Water Week (IWW-2022) organized by NWDA, MoJS, GOI during Nov. 01-05, 2022.
15. Sharma, M. K., Kumar, Pradeep, Sharma, Babita, Prasad, Beena and Bhanot, Kunarika (2022) Hydrochemical behaviour, its controlling processes and importance of p(CO2) signature of meltwater of River Bhagirathi in Upper Ganga Basin, India, Paper presented in 7th India Water Week 2022, India Expo Centre, Greater Noida, 1-5 November 2022.
16. Sharma, M. K., Kumar, Pradeep, Sharma, Babita, Prasad, Beena and Bhanot, Kunarika (2022), Hydrochemical behaviour, its controlling processes and importance of $p(CO_2)$ signature of meltwater of River Bhagirathi in Upper Ganga Basin, India, 7th India Water Week 2022 during 1-5 December 2022 at New Delhi.
17. Tomar, Anurag, Rajpal, A., Kazmi, A.A., Tyagi, V.K. (2022) Removal of Nutrients from Dairy Wastewater using Sequencing Batch Reactor. In:7th India Water Week conclave,1st -5th November 2022, Greater Noida, India Oct 29-31, 2022 (ORAL, Second Prize)
18. Tyagi, V.K, Balasundaram, G., Gahlot, P., Kazmi, A.A. (2022) " Thermal hydrolysis of sewage sludge: Organics solubilization, methane yield, and emerging contaminants & pathogens removal": 13th International symposium on Southeast Asian Water Environment, 13th-15th December 2022, Bangkok, Thailand (ORAL).
19. Tyagi, V.K., Arora, P., Kapoor, A., Kazmi,A.A. (2022) "Biorefinery of Municipal Solid Waste in a Circular Bio-economy: Case study of 100 TPD Mechanical-Biological Treatment Plant" in International Conference on Biotechnology for Sustainable Bioresources and Bioeconomy (BSBB-2022) organized by Indian Institute of Technology, Guwahati, India, December 7-11, 2022.

- **National Conferences (03 Nos. Key note/Lead Paper):**

1. Pandey, R.P. and R.V. Galkate (2022) "Impact of Climate Change on Occurrence of Regional Droughts". Invited lead paper presented in "31st National Conference on Innovative Resource Management Approaches for coastal and Inland Ecosystems to Sustain Productivity" and Climate Resilience, 13-15 Oct 2022, Navsari, Organized by Agricultural University, Navsari, Gujarat.
2. Pandey, R.P. (2022). Environmental Challenges and Water Resources Management for Resilient Ecosystem in Arid Regions invited Key paper presented in National Conference on Desert Ecosystems: Status, Emerging Challenges and Perspectives, November 15-16, 2022, Jaipur.
3. Pandey R.P. (2023). Challenges on sustainability of water resources for drinking water and irrigation. Water Summit: 2023 on"Water Security in India: Challenges & Prospects". Organised jointly by the Center for Advance Water Technology and Management and Gurugram University, Manav Rachna, International Institute of Research and Studies, 24th February 2023, Faridabad, 121004 – Haryana,

- **Book Chapters (08 Nos.):**

1. Ahmed Tawfik, Vinay Kumar Tyagi and Dominique Patureau Fate of emerging contaminants in anaerobic digestate. In: Tyagi, V.K., Kaoutar, A., Eskicioglu, C. (eds) Anaerobic Digestate Management. International Water Association Publishing (IWAP). UK. Pp. 327-338, Chapter 15,ISBN: 9781789062748
2. Akansha Bhatia, Ankur Rajpal, Bhaskar Jyoti Deka, A.A. Kazmi, Vinay Kumar Tyagi (2022) Valorization of Biowaste to Biowealth Using Cellulase Enzyme During Prehydrolysis Simultaneous Saccharification and Fermentation Process. In: Enzymes in the Valorization of Waste. Ed. Pradeep Verma, CRC Press, pp. 25-37, eBook ISBN 9781003187721
3. Manojkumar Y, Sridhar Pilli, R.D. Tyagi, PuspenduBhunia, Sumanth C, Vinay Kumar Tyagi and Ashok Pandey (2022) Per- and poly-fluroalkyl substances (PFASs): An introduction. In: Sustainable Treatment Technologies for Per- and Poly-fluoroalkyl Substances. Currents

Development in Biotechnology and Bioengineering Series. Elsevier Publishing. pp.1-12, ISBN: 978-0-323-99906-9.

4. Muntjeer Ali, Sridhar Pilli, PuspenduBhunia, R.D. Tyagi, Ashok Pandey and Vinay Kumar Tyagi (2022) Occurrence, fate, and persistence of perfluorinated compounds (PFCs) in wastewater treatment systems. In: Sustainable Treatment Technologies for Per- and Poly-fluoroalkyl Substances. Currents Development in Biotechnology and Bioengineering Series. Elsevier Publishing. pp. 207-233, ISBN: 978-0-323-99906-9.
5. Pallavi Gahlot, Kaoutar Aboudi and Vinay Kumar Tyagi (2022) Effect of digestate recirculation on anaerobic digestion performance. In: Tyagi, V.K., Kaoutar, A., Eskicioglu, C. (eds) Anaerobic Digestate Management. International Water Association Publishing (IWAP). U.K. Pp. 247-259. Chapter 11, ISBN: 9781789062748
6. Pallavi Gahlot, Kaoutar Aboudi, Ahmed Tawfik and Vinay Kumar Tyagi (2022) Biochar-augmented anaerobic digestate treatment. In: Tyagi, V.K., Kaoutar, A., Eskicioglu, C. (eds) Anaerobic Digestate Management. International Water Association Publishing (IWAP). UK. Pp. 265-282, Chapter 12,ISBN: 9781789062748
7. Pandey, RP (2021) Hydrological Drought in India – An institutionalized systemic hydrological management challenge (Case study 2). A policy-note contribution in FAO publication entitled "*A rapid review of drought risk mitigation measures – Integrated drought management*" (Author: Caroline King-Okumu; Eds: Maher Salman, FAO-UN and Daniel Tsegai, UNCCD). Rome, FAO, pp. 128-131, https://doi.org/10.4060/cb7085en.
8. Sanket Dey Chowdhury, R.D. Tyagi, Sridhar Pilli, Vinay Kumar Tyagi, Ashok Pandey and PuspenduBhunia (2022) Per- and poly-fluoroalkyl substances (PFASs) in water and wastewater In: Sustainable Treatment Technologies for Per- and Poly-fluoroalkyl Substances. Currents Development in Biotechnology and Bioengineering Series. Elsevier Publishing. pp. 299-327, ISBN: 978-0-323-99906-9.

- **Books (02 Nos.):**

1. Tyagi, V.K., Aboudi, K., Eskicioglu, C. (2022) Ananerobic Digestate Management. International Water Association publishing (IWAP). pp 350 (ISBN: 9781789062)
2. Sridhar Pilli, Puspendu Bhunia, Vinay Tyagi, Rajeshwar Tyagi, Jonathan Wong, Ashok Pande (2022) Current Developments in Biotechnology and Bioengineering Sustainable Treatment Technologies for Pre- and Poly-flourakyl Substances. Elsevier (UK). pp 350 (ISBN: 9780323999069)

TRAINING COURSE/WORKSHOP ORGNIZED (04 Nos.):

SN	Topic	Duration	Place
1	Training Course titled "Hands on Advanced Instrumentations in Water Quality Analysis" under NHP (Coordinator: Dr. M. K. Sharma)	5 Days 16-20 January 2023	Roorkee
2	Training Course titled " Environmental Data Processing" under NHP(Coordinator Dr. Pradeep Kumar)	5 Days 30 January - 03 February 2023	Roorkee
3	Training Course titled " Water Quality Monitoring & Management" under NHP (Coordinators: Dr. Rajesh Singh, Dr. V. K. Tyagi and Dr. Kalzang)	5 Days 13-17 February 2023	Roorkee
Following training programme is also proposed to be organized during the 2022-23			
4	Training Course titled "Water and Wastewater Treatment" under NHP (Coordinators: Dr. V. K. Tyagi, Dr. Rajesh Singh, and Dr. Kalzang)	5 Days 20-24 March 2023	Roorkee

AWARENESS ACTIVITIES ORGANIZED (04 Nos.):

1. One-day awareness workshop on "Water Conservation & Water Security" under "Azadi Ka Amrit Mohotsav" at Arya Swaroop Arya Saraswati Vidya Mandir, Delhi Road, Roorkee on 21 April 2022.
2. One-day training workshop on Social Awareness about Water Conservation and Water Security under "Azadi Ka Amrit Mohotsav" at Government Inter college, Bhalaswagaj, Bhagwanpur Block, Roorkee Tehsil, May 19, 2022.
3. One-day training workshop on Social Awareness about Water Conservation and Water Security under "Azadi Ka Amrit Mohotsav" at Jal Vihar Colony, National Institute of Hydrology, Roorkee Tehsil, June 15, 2022.
4. One-day training workshop on Social Awareness about Water Conservation and Water Security under "Azadi Ka Amrit Mohotsav" at Methodist PG Girls Degree College, Roorkee, August 3, 2022.

PROPOSED WORK PROGRAMME FOR THE YEAR 2023-24

S. N.	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	Dr. R. P. Pandey, (PI) Er. Jagdeesh Patra, Dr. Rajesh Singh Sh. N. K. Bhatnagar	6 Years (12/17-12/23) **Project Cost**: 18 Lakh Sponsored by: NHP Status: In-progress
2.	Anaerobic Co-digestion of Thermochemically Pretreated Organic Fraction of Municipal Solid Waste and Sewage Sludge: Effect on Process Performance and Microbial Community Development	Dr. Vinay Kumar Tyagi (PI)	5 Years (2018-2023) **Project Cost**: 106 Lakhs **Sponsored by**: DBT **Status**: In-progress
Collaborative Projects (Ongoing)			
3.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	Dr. Rajesh Singh (PI) Dr. R.P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 Years (07/21-06/24) **Sponsored by**: BHU **Status**: In-progress
4	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	Dr. Vinay Kumar Tyagi, (Co-PI) Dr. A.A. Kazmi (PI, IITR)	02 Years (01/22-12/23) **Sponsored by**: Central Pollution Control Board (CPCB)-NMCG
5	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	Dr. Vinay Kumar Tyagi, (Co-PI) Dr. A.A. Kazmi (PI, IITR)	4 Years (03/20-02/24) **Sponsored by**: Department of Science & Technology (DST)
Internal Study (Ongoing)			
6.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	Dr. M. K. Sharma (PI) Dr. Suhas Khobragade Dr. Rajesh Singh	2 Years (04/22-03-24) **Status:** In-progress
7.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Dr. Rajesh Singh (PI) Dr. R. P. Pandey Dr. Sumant Kumar Dr. Pradeep Kumar Dr. M. K. Sharma Dr. V. K. Tyagi Dr. Kalzang Chhoden	3 Years (07/21-06/24) **Status:** In-progress
8.	Simulation of Non-Point Source Pollution Processes in Song River	Dr. Pradeep Kumar (PI) Dr. M.K. Sharma Dr. Rajesh Singh	4 Years (11/19-10/23) **Status:** In-progress
9.	Hydrological Studies for the Conservation of Rewalsar Lake	Dr. Kalzang Chhoden (PI) Dr. Rajesh Singh Dr. R. P. Pandey Dr. Pradeep Kumar Dr. Vinay Kumar Tyagi Er. Omkar Singh Dr. Shuhas Khobragade Dr. D.S. Malik, GKU,Haridwar	3 Years (12/22-11/25) **Status:** Proposed
10.	Comprehensive evaluation of disinfection units of STPs in Ganga	Dr. Vinay Kumar Tyagi (PI) Dr. Rajesh Singh	3 Years **Status:** Proposed

	basin: Occurrence and control the formation of emerging oxidation precursors	Dr. Mukesh K. Sharma Dr. Pradeep Kumar Er. J. P. Patra Dr. Kalzang Chhoden Dr. R.P. Pandey	
Consultancy Projects (Ongoing)			
11.	Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-1 Power Station, NHPC	Dr. J. V. Tyagi Dr. R.P. Pandey Dr. Rajesh Singh (PI) Dr. M.K. Sharma	15 Months (12/21-03/23) **Sponsored by:** Innovante Water Soluation Pvt. Ltd. Roorkee **Project Cost**: Rs. 3.245 Lakh **Status:** On-going
12.	Performance evaluation of Nano Catalytical Instant Water Converter (NCIWC) equipment for water and wastewater treatment	Dr. J.V. Tyagi Dr. R.P. Pandey Dr. Rajesh Singh (PI) Dr. Sumant Kumar Dr. Vinay Tyagi Dr. M.K. Sharma Dr. Pradeep Kumar	06 Months (05/22-11/22) Further Extension Requested **Sponsored by:** Envirogreen Minetech India Pvt. Ltd., Indore M.P. **Project Cost**: Rs. 5.90 Lakhs **Status:** On-going
13.	Water Quality Studies for Tehri Reservoir Tehri HPP (4x250MW)	Dr. Sudhir Kumar Dr. R.P. Pandey Dr. M.K. Sharma (PI) Dr. Pradeep Kumar Dr. Rajesh Singh	2 Years (02/23-01/25) **Sponsored by:** THDC, India Limited **Project Cost:** Rs. 6.91 Lakh **Status:** On-going
14.	Hydrological Study for Water Availability Assessment in Sukhnai River and Runoff Diversion to Saprar Dam	Dr. R.P. Pandey (PI) Dr. Pradeep Kumar Dr. Rajesh Singh Dr. V. K. Tyagi Dr. Kalzang Chhoden	06 Months (03/23-09/23) **Sponsored by:** Irrigation Construction Division, Mauranipur **Project Cost:** Rs 29.50 Lakh **Status:** Ongoing
15.	VOC Analysis for Water Samples	Dr. Sudhir Kumar Dr. R.P. Pandey Dr. M. K. Sharma (PI) Dr. Rajesh Singh Dr. Pradeep Kumar	**Duration:** 45 days (02/23-04/23) **Sponsored by:** NEERI, Nagpur **Budget:** Rs. 2,12,400/- **Status**: Ongoing
16.	Hydrological Study for the Design of Drainage System for Safe Disposal of Upland Runoff Passing through KV Bhimtal	Dr. R.P. Pandey (PI) Dr. Pradeep Kumar Dr. Rajesh Singh Dr. V. K. Tyagi Dr. Kalzang Chhoden	**Duration:** Two Weeks (07/23-08/23) **Budget:** Rs. **9**,44,000/- **Status**: Ongoing
17.	Preparation of District Action Plan (DAPs) under JJM in the State of Utterakhand) Jal Jeevan Mission (CS-271-	SUDHIR KUMAR Dr. R.P. Pandey (PI) Dr. Pradeep Kumar Dr. Rajesh Singh Dr. V. K. Tyagi Dr. Kalzang Chhoden MKS	**Duration:** 07 Months (06/23-12/23) **Sponsored by:** Jal Jeevan Mission, Uttarakhand **Budget:** Rs. 1,06,20,000/- **Status:** Ongoing

Study – 1 (Sponsored Project)

1. **Title of the Study:** Water Efficient Irrigation by using SCADA system formedium Irrigation Project (MIP) Shahnehar
2. **Study Group:**

Project Investigator/Co-Project Investigator
Dr. R.P. Pandey, Scientist G. Er. Jagdish Prasda Patra, Scientist D Dr. Rajesh Singh, Scientist D, Sh. N. K. Bhatnagar, Scientist B
Collaborating Agency
Department of Irrigation & Public Health Engg. (I&PHE), Hydrology C&M Division, Tutikandi, Shimla-4. Himachal Pradesh

Type of study: PDS
Total Project Cost: Rs.75.0 lakh (**Funded by NHP)**
NIH Cost Allocation Rs. 18.1 lakh

Project Duration: **3-years**

Date of start: **December, 2017**

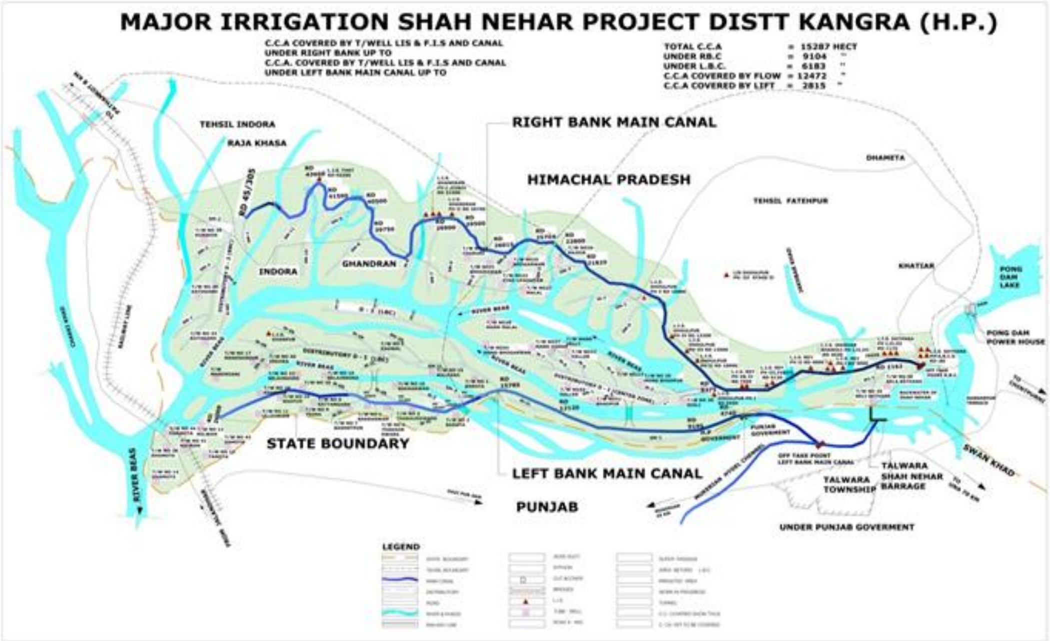
Scheduled Date of Completion: **March, 2023 (after extension)**

OBJECTIVES OF THE STUDY:
The primary objectives of this study is to **Devise a suitable approach to improve irrigation water use efficiencyin Shah Nehar Project.** The specific objectives of the study are as follows:

- To develop monitoring, supervisory control and modernize system for Agriculture Irrigation water.
- Paradigm shift in the approach from a supply-based system to a demand-based sustainable system.
- Real time monitoring of water availability at head works.
- Performance evaluation of Left Bank Canal and Right Bank Canal of MIP Shah Nehar Project.
- Identify issues that need to be addressed to improve project performance
- Suggest measures to improve water use efficiency &sustainability up to farm level
- Integrating Warabandi with SCADA system.

Study Area : Shah Nehar Command Area, Himachal Pradesh
Shah Nehar Irrigation Project in District Kangra, Himachal Pradesh is first Major Irrigation Project of the state amounting to Rs.143.32 crore was approved by the HP Govt to irrigate 15287 hectares of land of 93 villages situated on right and left bank of river Beas by constructing two numbers of main canals on each bank with a length of 45.30 and 25.69 km respectively. The water was fetched from outfall of Pong Dam by signing agreement between Govt. of HP and Punjab Govt. on 4/8/1983.The index map of Shah Nehar project command area is given in Figure below.

Whole of the Right bank canal enroots through the jurisdiction of Himachal Pradesh whereas about 4.0 Km of LBC out of 25.69 km falls in the state of Punjab. Out of total cost of Rs 143.32 crore the Govt. of Punjab was to share Rs 88.49 crore and remaining Rs 54.83 crore was to be borne by the Govt. of H.P. Later on due to price escalation revised DPR was prepared and approved to the tune Rs 387.17 crores at price level 2010 in 110th meeting of advisory committee of CWC. The project was included under Accelerated Irrigation Benefit Program (*AIBP*) with 90% Central Aid and balance 10% had to be shared by Govt. of Punjab and HP in the ratio of 61.74% and 38.26%.



Description of the Problem

At present the Shah Nehar project experiences improper distribution of water into the agricultural fields resulting into low yield of crops and therefore necessity of water efficient irrigation system by using SCADA. The primary objectives of the proposed study are to enhance water use efficiency, minimize water losses and to increase productivity in the command area of Shah Nehar project. The Shah Nehar project is first major Irrigation project in Himanchal Pradesh. Presently, water is being supplied to 93 villages comprise of 15287 hectares Culturable Command Area (CCA) through several outlets provided in the main canal. From each outlet the water is transported by gravity or lift scheme to each chak proposed in the command area development. The water demand of each outlet is based on the cropping pattern proposed in the respective chak. The roster of water demand is based on the warabandi schedule prepared by the Irrigation & Public Health Department in consultation with Krishi Vikas Sangh/Water User Associations.

It is proposed to quantify available water at the head-works of the canal system during cropping period, estimation of irrigation water requirement for existing cropping pattern, assessment of losses at the conveyance, distribution and application of water in the command area. The study will be helpful in identification of the potential area which requires appropriate land and water management intervention for improvement of water use efficiency. Further the study will be useful in quantifying the potential of improvement in irrigation water use efficiency in the Shah Nehar command area.

The HP IPH Department has listed the problems of irrigation water management in the Shah Neha Project based on input received from the farmers, observations made during their field visits and consultation with specialized agronomists as follows:

- ✓ Non availability of water during peak demand of crops at the tail end of command area.
- ✓ No check over theft of water from the main canals.
- ✓ Irrigation systems play vital role for sustainable agricultural development in Himachal Pradesh, but major problem of which is rather low efficiency of water use.
- ✓ No accountability due to absence of water accounting & audits.
- ✓ Poor and low consistency management of the irrigation systems efficiency.
- ✓ Lack of reliable monitoring network and supervisory control for irrigation systems.
- ✓ Non availability of effective decision making tool to improve irrigation management.
- ✓ Huge water loss due to random irrigation process.
- ✓ Lack of awareness about modern and water efficient irrigation methods.

Proposed Methodology

The purpose of the proposed study is to examine the present status of the Shah Nehar Irrigation Project water use efficiency, quantify the water losses in the main canal system & distributaries, water courses and field application. Determination of time based crop water demand and supply for existing cropping pattern and identification of irrigation system components needing water management interventions to improve water use efficiency of system and maximize the benefit from the Shah Nehar project. The work component will include the following:

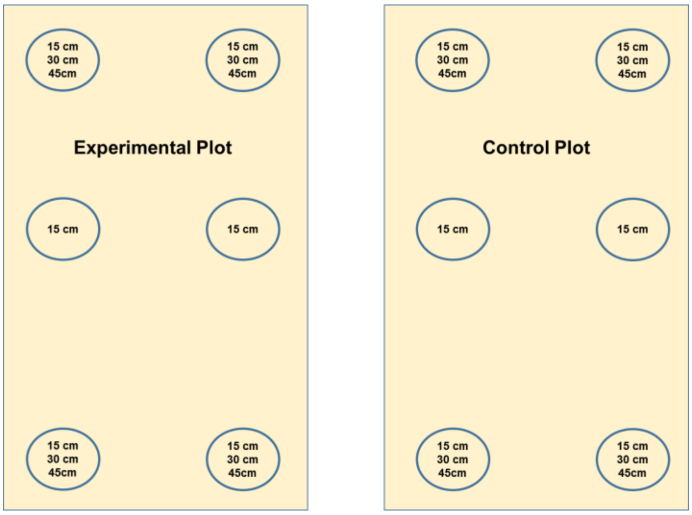
1. Monitoring of supply and distribution of water in conveyance, distributary outlets and the on form irrigation application at selected experimental sites.
2. Assessment of the real time availability of water at head works, at various outlets in the main canal and tail ends of distribution system during the Rabi, Kharif and Zaid crop period.
3. Assessment of site specific water requirement for suitable time-steps during cropping periods in different seasons
4. Devising a methodology regarding equitable distribution of water to the farmers in each crop period from head to tail reaches by using SCADA.
5. Develop a system of water supply database of quantum of water used to each beneficiary so the charges can be levied accordingly.
6. Devising a possible system of change in cropping pattern owing to real time monitoring of available water at various reaches of the canal.
7. Identification and evaluation of intervention to minimize water losses throughout the canal and distribution system, water courses and in the field application to enhance the water use efficiency.

From the data collection and analysis of the data, Water efficient Irrigation by using SCADA System will be provided so that water can be used more efficiently and hence it will increase the effectiveness of the Irrigation Project.

Progress of Work

The team NIH Scientist visited study area and conducted detailed survey of Shahnehar Project Command Area, along with Himachal Pradesh I &PHE department officials. Detailed plan for the selected experiment sites was prepared after discussion with I&PHE officials. after field survey to finalize the project modalities and work plan for the study. The pilot sites for detailed experimentation have been identified. Field investigation and instrumentation for field experimentation for the study has been finalization after meeting with the project team of the lead organization (I&PHE, Shimla) to setup monitoring schedule. The irrigation command site for SCADA implementation has been finalized.

1. The meteorological data for the assessment of present irrigation requirement has been collected from BBMB meteorological station at pong dam site.
2. The estimation of Pet and the crop water requirement for the study has been worked out.
3. The Himachal Pradesh I &PHE department has been further requested to obtain data from Kangra Agriculture College/other stations in the vicinity of the project site.
4. Base maps for the study sites have been prepared.
5. The experimental sited identified are as follows:
6. Lift Irrigation Scheme (LIS) Sthana, Terrac Sub-Division—for SCADA experimentation.
7. Selected sites/field plots in distributary-1 (D-1) command area –Badukhar Sub-Division -- for experimentation-1 in middle reaches.
8. Selected sites/field plots in distributary-2 (D-2) command area- for experimentation-2 in tail reaches.
9. Field investigations have been carried out and the layout of the experimental plots for installation of moisture sensors for measurement of crop root-zone moisture at the three sites have been prepared as follows.



S.N. (1)	Instrument/ Sensor (2)	At one Site (3)	For Three Site (4)=(3)*3
1	Moisture and temperature sensor • at 15, 30, 45 cm depth • at 15 cm depth	 8 4	 24 12
2	Flow meter (Discharge measurement)	3	9
3	Data logger/transmitter	1*	3*

10. Department of I & PHE, Shimla, Govt. of Himachal has processed for procurement of discharge & Moisture measurement sensor and installation in the field. The procurement is under process at present.
11. Installation of sensors and telemetry system for soil moisture monitoring and data transmission. (Work in progress).
12. Estimation of Irrigation requirement for different crops in the Shahnehar Command areas using meteorological data has been carried out and it will be presented in the working group meeting for comments/suggestion, if any. The summary of the estimated crop water requirement is as follows.

    Crop Water Requirement (CWR), Potential Evapotranspiration (ETo) and Irrigation scheduling in the subtropical humid region are crucial in efficient use of irrigation supply, water resources assessment, hydrology and designing the irrigation projects as the supply of water through rainfall varies in space and time. In this context, dependable monthly rainfall at 80% and 50% probability level during the period 1982-2018 has been to assess distribution of effective rainfall and the minimum expected rainfall during the crop growing period in Shahnahar command area. FAO (Food and Agriculture Organisation) CROPWAT 8.0 crop simulation model has been used to estimate reference evapotranspiration (ETo), effective rainfall, crop water and irrigation requirement and irrigation scheduling for the Rice and Wheat crop. It is found that the average annual ETo is 4.11 mm/day and varies with highest value of 6.67 mm/day in the month of June and lowest value in January (1.99 mm/day). From the observation of probability analysis at P80 and P50, it is also found that the maximum deficit can be in the order of 33.02 mm in month of July and minimum deficit of 1.32 mm rainfall in the month of November. For seasonal agricultural planning, the 80% dependable rainfall level may be considered for safer and better irrigation management planning in the study area.

Further Proposed Work Plan for next year

1. Application of field irrigation under measured and controlled conditions. (replication at three sites).
2. Quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application methods.
3. To evolve irrigation scheduling (revision) considering the crops, soil moisture and prevailing climatic conditions.
4. Demonstrations and conducting workshops on OFWM practices for all the stakeholders including farmers.
5. To review the role of existing Water Use Associations (WUA) and suggest suitable
6. To extend the improved/scientific modifications for encouraging the better OFWM practices and equitable water distribution among the farmers.
7. Review of the existing Cropping patterns during different sowing seasons and suggest suitable crops for each season to enable optimum utilization of available water.

Deliverables:

1. Estimates of water availability at headwork’s and irrigation water requirements for various crops a different growth stages & time period.
2. Quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application methods.
3. Identification of components of irrigation system needing intervention to enhance water use efficiency.
4. Experimental assessment of SCADA based approach in the enhancement of water use efficiency.

Study - 2 (Sponsored Project)

1. **Title of the Study:** Anaerobic co-digestion of organic fraction of municipal solid waste and sewage sludge: Effect of thermal-chemical pretreatment on process performance and microbial community development

2. **Study Group:**

Project Investigator	Dr. Vinay Kumar Tyagi, Sc. 'D', EHD
Research Staff	Ms. Banafsha Ahmed, PhD Student Mr. Ali Mohammad Rahmani, PhD Student

3. **Type of Study:** Sponsored Study**,** **Budget:** Rs. 103.6 Lakhs

4. **Nature of Study:** Applied Research

5. **Date of start:** April 2018

6. **Scheduled date of completion:** June 2023

7. **Duration of the Study:** 5 Years

8. **Study Objectives**
   a) Improving the efficiency of anaerobic digestion by thermo-chemical pretreatment of co-mixed substrate (OFMSW+sewage sludge)
   b) To address the influence of anaerobic co-digestion and thermo-chemical pretreatment on microbial community.

9. **Statement of the Problem:**

Increasing urbanization and poor waste management practices are leading to the rapid build up of solid waste heaps in the major urban cities throughout the India. Due to lack of proper treatment techniques, the waste (organic fraction of municipal solid waste, OFMSW and sewage sludge, SS) ultimately ends up into the landfills that is the least preferred waste disposal technique. Which leads to the wastage of land resource as these areas become unfit for any other uses due to ground water pollution by leachates, soil pollution, greenhouse gas emissions (a global issue) and the odour generation.

Anaerobic co-digestion (ACoD) method is one such technique that is generally used to assimilate different waste material to improve the conventional anaerobic treatment process and recover energy rich biogas. But the opportunities are missed to maximize the recovery of biogas production from the facilities due to presence of complex organic materials in OFMSW and SS that obstruct their biotransformation of substrate i.e. rate limiting step of the process. Despite the fact that co-digestion can increase the efficiency of biogas generation these complex organic compounds are limitations of ACoD. Therefore, pretreatment (thermal-chemical) of the mixed substrate (OFMSW and SS) can be interesting option to achieve a high organic matter solubilisation, increase in acidogenic and methanogenic biodegradability, and subsequent improvement in biogas generation. Integrating pre-treatment with co-digestion of OFMSW and SS has a number of potentially positive outcomes for the anaerobic co-digestion: increased stability of the process; increased specific biogas yields and methane content of biogas produced; maximizing the substrate availability for microbial community; reduction in energy requirements during the digestion process; reduction in the operational time i.e. HRT and SRT; reduced volume of reactor will provide economic feasibility; reduced use of landfills; utilization of bio-solids (digestate) as soil conditioners; sustainable management plan for OFMSW and sewage sludge.

Limited information is available in literature about the pre-treatment of combined municipal solid waste and sewage sludge for anaerobic co-digestion process and effect on biogas production.

Hence, the primary aim of this study is to investigate the co-digestion at different waste composition and develop an energy efficient pre-treatment method for maximum biogas recovery. On other hand, according to the situation in India where a renewable energy program has been initiated in the recent past, the introduction of anaerobic digestion into urban areas seems to be a value addition. The failures of various projects are more due to technical problems, inadequate planning or inappropriate management. There is a need of research on the aspect of stakeholder's preference towards the benefits of a biomass to bioenergy project. One of the objectives of the project deals with the preference hierarchy of the various stakeholders for sustainability of a biomass project. The benefits derived from the bio-waste to bioenergy project can be classified as: (a) avoidance of danger from the burning of biomass residues. (b) creating additional job opportunities for local people. (c) transfer of technology and knowledge in renewable energy. (d) Increasing the usage of renewable energy and local content. (e) reduction of GHG emissions.

10. Methodology:

The research project has been structured in six work packages (WP):

WP 1: Waste characterization

Milestone Expect: Defining characteristics of the samples in order to adjust feeds.

WP 2: Optimization of best treatment conditions for OFMSW+Sewage sludge

Milestone Expect: Definition of best total solids percentage (%TS), best sludge combination, Optimum OFMSW to sewage sludge ratio.

WP 3: Optimization of thermo-chemical pretreatment of waste

Milestone Expect: Selection of optimum condition of thermo-chemical pretreatment

WP 4: Effect of thermo-chemical pretreatment on biogas production and microbial community development

Milestone Expect: Selection of optimum conditions of pretreatment in order to maximize the methanogenic activity and biogas production. Deep insight on the reactor functioning by microbial community study under different treatment conditions/ Identification of microbial community changes by under no-pretreatment and pretreatment conditions.

WP 5: Semi-continuous operation

Milestone Expect: Best organic loading rate and hydraulic retention time.

WP 6: Pilot scale study

Milestone Expect: Proof of upscaled process

WP 6: Results analysis, drawing conclusion and reporting

Milestone Expect: Document summary of results, National and International research publications and conferences.

11. Timeline:

Task	Description	Months									
		6	12	18	24	30	36	42	48	54	60
1	Litearture Review & Characterization of the wastes										
2	Optimization of best treatment conditions for OFMSW+Sewage sludge										
2.1	Effect of co-digestion on biogas production										
2.2	Best sludge combination with OFMSW										
2.3	Best TS percentage of substrate										
2.4	Best OFMSW:Sludge mixing ratio										
3	Optimization of thermo-chemical pretreatment										
4	Batch anaerobic co-digestion experiments on pretreated waste, microbial community analysis										
5	Semi-continuous operation (HRT & OLR)										
6	Pilot study										
7	Data analysis										
	Milestone										
	Defining characteristics of OFMSW & SS										
	Best TS percentage, best sludge combination, Optimum OFMSW to sewage sludge ratio.										
	Selection of thermo-chemical pretreatment conditions										
	Assessment of thermal-chemical pretreatment effects on microbial community & biogas production.										
	Best HRT and OLR										
	Proof of upscaled process										
	Final report, National and International research publications.										

12. Objectives and achievement during last twelve months:

S. No.	Objectives	Achievements
(i)	**Semi-continuous operation**	The semi-continuous anaerobic co-digestion (AcoD) of thermal and thermal-alkali pre-treated organic fraction of municipal solid waste (OFMSW) and sewage sludge (SS) was studied under variable hydraulic retention times (HRT) and organic loading rates (OLR). Digesters were operated under control (non-pre-treated), thermally pre-treated (125℃), and thermal-alkali pre-treated (125℃-3g/L NaOH) conditions at variable OLRs at 2.5, 4.0, 5.1 and 7.6 kgVS/m^3.d and corresponding HRTs of 30, 20, 15, and 10 days. • Thermal-alkali pre-treatment shows the best methane yield and VS removal • Highest CH_4 yield (0.445 m^3/kgVS) achieved at 15 days HRT and 5.1 kg VS.m^{-3}/d OLR • Methane composition in biogas ranged from 72-78% under steady state conditions • Highest VS removal (52%): 57 and 11% higher than control and thermal pre-treatment • > 70-80% bacterial reads: *Firmicutes*, *Bacteroidetes*, *Chloroflexi*, *Proteobacteria*, *Actinobacteria* • Key archaeal community was acetoclastic methanogens *Methanosarcina* and *Methanothrix* • Thermal- alkali pretreatment shown highest energy gain with an energy ratio of 1.25.
(ii)	**Pilot scale study**	The pilot scale digester (100 kg capacity) operation ongoing from January 2023 and will be keep operating for two different pretreatment conditions of thermal and thermal-alkali pretreatment.

13. Recommendation / Suggestion:

S. No.	Recommendation / Suggestion	Action Taken
1.	No comments	--

14. Analysis & Results:

The semi-continuous anaerobic co-digestion (AcoD) of thermal and thermal-alkali pre-treated organic fraction of municipal solid waste (OFMSW) and sewage sludge (SS) was studied under variable hydraulic retention times (HRT) and organic loading rates (OLR). Digesters were operated under control (non-pre-treated), thermally pre-treated (125℃), and thermal-alkali pre-treated (125℃-3g/L NaOH) conditions at variable OLRs at 2.5, 4.0, 5.1 and 7.6 kgVS/m^3.d and corresponding HRTs of 30, 20, 15, and 10 days. The 10 and 43% higher methane yield (0.445 m^3/kgVS) and, 11 and 57% higher VS removal (52%) was achieved for thermal-alkali pre-treated digester at 5.1 kgVS/m^3.d OLR over thermally pre-treated (0.408 m^3/kgVS, 45% VS removal) and control digesters (0.310 m^3/kgVS, 33% VS removal), respectively. Thermal and thermal-alkali digesters were failed on increasing the OLR to 7.6 kgVS/m^3.d, whereas, the control digester becomes upset at 5.1 kgVS/m^3.d OLR. Metagenomic study revealed that *Firmicutes*, *Bacteroidetes*, *Chloroflexi*, *Euryarchaeota*, *Proteobacteria*, and *Actinobacteria* were the predominant bacterial population, whereas

Methanosarcina and *Methanothrix* dominated the archaeal community. Energy balance analysis shown that thermal alkali pretreatment shown a highest positive energy balance of 114.6 MJ/ton with an energy ratio of 1.25 in comparison with thermally pretreated (81.5 MJ/ton) and control samples (-46.9 MJ/ton). Life cycle assessment (LCA) was performed to visualize the environmental impacts of anaerobic digesters treating pre-treated OFMSW

15. **End Users / Beneficiaries of the Study:** Municipal corporation

16. **Deliverables:** Technical report and research papers

17. **Major items of equipment procured:** None

18. **Lab facilities used during the study:** Bioenergy Lab, IIT Roorkee

19. **Data procured or generated during the study:** Semi-continuous operation and Pilot study related

20. **Study Benefits / Impacts:**

Municipal corporations will be the direct beneficiary, as the load of MSW handling will be lessened. Moreover, the obligation of stringent rules for the disposal of sewage sludge can be pacified as the sludge will be further used as a medium for electricity generation that can power the WWTP and the end product of digestion will be a highly stabilized end product that will not be harmful to that extent as the undigested sludge. **Industrial sector** i.e. different consultants and companies can get involved and, develop the design based on our results for better efficiency and ensure successful implementation at field scale. Moreover, a newly developed waste to energy recovery method can be circulated in the private sector and that can give green credits to the organization and it can be a stepping-stone to sustainable development. **Researchers:** Co-digestion and advanced pretreatment are emerging technologies with limited data availability on the integrated approach of both methods for organic waste treatment. The introduction of the findings of this study will benefit researchers working on municipal solid waste and sludge treatment as the option for two problematic waste management. In addition, the availability of large-scale microbial community data will aid in the development of fresh approaches involving manipulation of microbial composition and the formulation of inoculum for greater process efficiency.

21. **Involvement of end users/beneficiaries:** None

22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes

23. **Shortcoming/Difficulties:** None

24. **Future Plan:**

(i) Continuous operation study of pilot digester under variable treatment scenario

Study – 3 (Collaborative)

1. Title of the Project: Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India

2. Project Team

Lead Investigator	Dr. S. P. Rai, Assoc. Professor, Geology Dept., BHU Varanasi
Collaborator 1	Dr. Rajesh Singh, Sc. D, EHD, NIH Roorkee
Collaborator 2	Dr. Noble Jacon, Sc. G, Hydrology Section, BARC Mumbai
Collaborator 3	Dr. Laszlo Palcsu, Sr. Researcher, ICER, Hungarian Academy of Sciences, Hungary

3. Type of Study: Internal Study, **Budget:** Rs. 10 lacs

4. Nature of Study: Applied Research

5. Date of start: July 2021

6. Scheduled date of completion: June 2024

7. Duration of the Study: 3 Years

8. Objectives

i) Identification of recharge sources and zones of aquifer system
ii) Estimation of residence time, distribution and flow velocity of groundwater
iii) Understanding interaction with aquifer and surface water bodies
iv) Understanding rock water interaction affecting the water quality and assessment of impact of anthropogenic activities on groundwater.

9. Statement of the Problem

Understanding the properties of available water resources is a key factor for sustainable watermanagement. These properties include recharge conditions of the infiltration area, safe yield ofgroundwater, transit times, direction and velocity of an accidental pollution, hydraulicconnection between aquifers, water – rock interactions affecting the water quality etc. Theseprocesses cannot be understood without the integrated approach of isotope and waterchemistry. The investigation will help to better manage the groundwater resources of the studyarea and it will be a model study for the country too.Exploitation of depleting water resources results in deterioration of water quality. Groundwatercontamination has also emerged as a serious issue that has posed serious threat to the peopleliving in the Ganga River Basin. Groundwater, which is extensively used for drinking, cookingand/or irrigation, is contaminated with arsenic in many part of the Ganga Basin and is havingsevere detrimental effects on human health. Presently, the main problem of depletion ofgroundwater in Ganga Basin is due to the unsustainable abstraction of groundwater (Rodell etal., 2009; Tiwari et al., 2009). As the groundwater level is declining, people are drilling todeeper aquifers, to meet the groundwater demand. In the arsenic affected areas, deeper aquiferhas been tapped for the extraction of groundwater to meet the drinking and other demands. Thegroundwater extracted from deeper horizons is becoming the most important fresh waterresource in Ganga River Basin. However, little is known about the deeper aquifers which arein semi-confined and to confined condition.Understanding the properties of available water resources is a key factor for sustainable water management. These properties include recharge conditions of the infiltration area, safe yield of groundwater, transit times, direction and velocity of an accidental pollution, hydraulic connection between aquifers, water – rock interactions affecting the water quality etc. These processes cannot be understood without an integrated approach of isotope and water chemistry.

Keeping in view of same, the study aims at identification of recharge sources and zones of aquifer system, understanding the surface and groundwater interactions, and the rock water interaction and anthropogenic activities affecting the groundwater quality.

10. Approved Action Plan/ Methodology:

i) Thorough review of aquifer system and water quality status of the study area.
ii) Collection and characterization of the water samples from the study area for physico-chemical, bacteriological, and isotopic parameters.
iii) Geochemical, isotopic, and statistical modeling to understand the rock-water interaction, recharge zones, surface water interactions, and anthropogenic influence.

11. Timeline (Approved):

Sr. No.	Major Activities	2021-22			2022-23				2023-24				2024-25
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
1.	Field Investigation and sampling plan												
2.	sample collection and analysis												
3.	Geochemical, isotopic, and statistical modeling												
7.	Publications												
8.	Interim Report												
9.	Final Report												

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared.
2.	Sample Collection and Analysis	• Pre-monsoon (2022) samples were collected from the selected locations. • Analysis for organoleptic, major ions, coliforms, and stable isotopes in the collected samples completed and analysis of trace metals and tritium (3H) is in progress. • Based on the in-situ parameters (EC, pH and ORP) and major ion chemistry data, major hotspot sites has been identified for post monsoon sampling.
3.	Scientific Publications	• 01 research paper in international journal (under review). • 01 research paper in international journal (under submission).

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	No specific suggestion	--

14. Analysis & Results:

Upgrading literature and data collection

- The information related to geomorphology, geology, soil chemistry and mineralogy of the study area were extracted from the published reports of CGWB, GSI and SGWB.
- Important available data such as SRTM DEM, water level data, rainfall data, and borehole data are also acquired.

Field Investigation and sampling plan

The Middle Ganga Basin is characterized by multi aquifer system and the principal aquifer systems has been classified into four major types: Aquifer I which varies from soil depth to 150 m bgl, Aquifer II - 160-240 m bgl, Aquifer III - 260-370 bgl, and Aquifer IV - 370-480 m bgl (CGWB, 2020). Based on this, the major sampling strategy was designed to collect water samples from different borehole depth following the grid sampling at 15km × 15km. It was planned to collect groundwater samples from shallow and deep wells from each grids. However due to the limited number of deeper wells (>100 m bgl) tapped by government water supply Jal-Kal and irrigation tubewells, a fewer number of water samples could be collected. Groundwater samples from different borehole depth along with coordinates were collected from the Varanasi and adjoining districts encompassing an approximate area of 20,0000 sq. km.for the Pre Monsoon season 2022 were collected (Fig. 1).

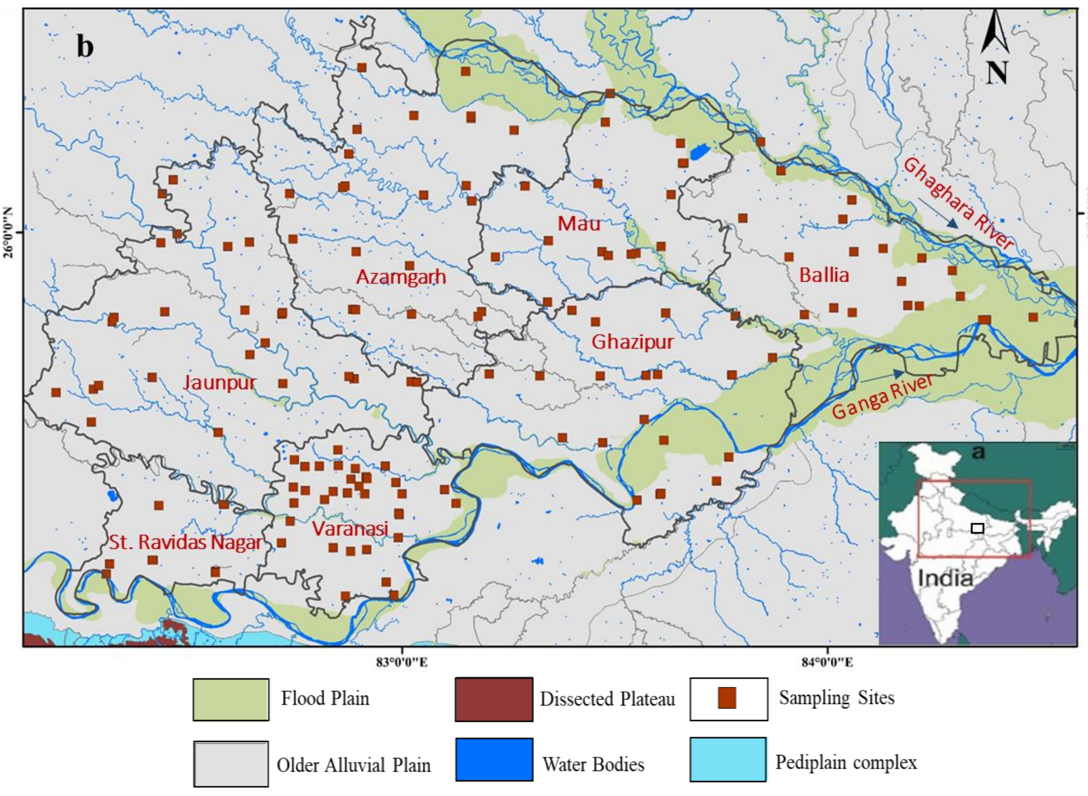


Fig. 1.(a) Ganga River Basin and black box showing study area,**(b)** the geomorphological settings of the study area, districts, major rivers along with the sampling sites.

Sampling & Analysis

- The handpumps/tubewellsof the identified locationwere continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017).The parameters such as coordinate, elevation, temperature, borehole depth, pH, ORP and EC were measured at the sampling sites.

- Alkalinity, HCO_3 and CO_3were determined titrimetrically within a day, while major ions were measured within a month after entire groundwater sampling with Ion chromatograph.

15. **End Users / Beneficiaries of the Study:** Policy makers and planners of State/Central Government Organizations

16. **Deliverables:** Technical report and research papers, GW recharge sources and aquifer zonation, SW-GW interaction, and rock-water and anthropogenic influence on water quality.

17. **Major items of equipment procured:** None

18. **Lab facilities used during the study:** Hydrogeology Laboratory (BHU),Water Quality Laboratory (NIH), Isotope Laboratory (NIH)

19. **Data procured or generated during the study:** Water quality data of the study area and anthropogenic influence on the water quality.

20. **Study Benefits / Impacts:**
    The outcome of the project would help the managers for the sustainabledevelopment and management of this scarce resource and plan for augmentation measures toensure continuous supply of water to meet the demands of the people in the region.The project will also explore the remedial measures for providing safe and clean water to the densely populated regions of the MGB.

21. **Involvement of end users/beneficiaries:** Water Resources & Environment Directorate, Varanasi and adjoining districts, CGWB Lucknow

22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes

23. **Shortcoming/Difficulties:**None.

24. **Future Plan:**

- To identify the major hotspots sites based on the major and trace metals analysis.
- To conduct post-monsoon sampling for those identified hotspots to understand the monsoonal recharge.
- Geochemical and statistical modelling.

Study – 6 (Internal Study)

1. **Title of the Study:** Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants

2. **Study Group:**

<table>
<tr><th colspan="3">Study Team</th></tr>
<tr><th>NIH, Roorkee</th><th>DRC, Kakinada</th><th>CGWB, Southern Region, Hyderabad</th></tr>
<tr><td>Dr. M. K. Sharma, Sc. E (PI)
Dr.SuhasKhobragade, Sc. ‘G’
Dr. Rajesh Singh, Sc. ‘D’</td><td>Dr. Y. R. S. Rao, (PI)
Sc. G & Head</td><td>Sri J. Siddhardha Kumar (PI)
Sc. E & Head</td></tr>
<tr><td colspan="3">Supporting Staff
Mrs. Babita Sharma, SRA
Mrs. Beena Prasad, RA
Mr. P. R. S. Rao, PRA</td></tr>
</table>

3. **Type of Study:** Internal
4. **Nature of Study:** Applied Research
5. **Date of Start:** April 2022
6. **Scheduled date of Completion:** March 2024
7. **Duration of the Study: 2** years
8. **Study Objectives**
   i) To study the groundwater level fluctuations in Krishna-Godavari Deltas
   ii) Characterisation of groundwater using Hydro-chemical and Hydrogeochemical investigation
   iii) Isotopic Characterisation of groundwater
   iv) To study the status of Emerging Contaminants in the groundwater, their sources and its impacts on human health

9. **Statement of the Problem**

Krishna and Godavari rivers are major and large rivers in Peninsula India. Water availability is more in Godavari River. Krishna delta has the water scarcity problem due to unavailability of water in Krishna River. So Andhra Pradesh government took the decision to interlinking the rivers through Polavaram canal. Flood waterfrom the Godavari River could be diverted to the paddy growing region of Rayalaseema, which often suffers from insufficient water. In order to link the two rivers a 174 km-long canal, known as the Polavaram Right Canal, was constructed and supplied with pumps that will remove excess water from the Godavari River and send it to the Krishna River. Paddy farmers in the Krishna Delta are the main beneficiary of the linking of the two rivers. Diverted water will also provide Amaravati, the planned state capital, with drinking water. The project is seen as a means to ensure the future water and food security of Andhra Pradesh.

Groundwater situation in different parts of India is diversified because of variation in geological, climatological and topographic set-up. Annual water level fluctuation of premonsoon has shown a fall in water levels for 59 % of the area, predominantly in Rayalaseema region. During post-monsoon about 90% area of the state experienced rise in annual water level fluctuation. Aquifer wise water level analysis shows that during pre-monsoon season shallowest water levels are observed in all the formations except in Intrusives. Deepest water levels are observed alluvium, Limestone and BGC. During post-monsoon season, shallowest water levels are observed in all formations except in Intrusives and Laterites. Deepest water levels are observed in Gneiss, Granite, Limestone, Quartz and Sandstone (CGWB GW Year Book 2019-20 AP).

Geo-environmental conditions have a marked influence on the groundwater quality. Hydrogeochemical studies relevant to the water quality explain the relationship of water chemistry to aquifer lithology. Such relationship would help not only to explain the origin and distribution of dissolved constituents but also to elucidate the factors controlling the groundwater chemistry. Further, groundwater quality in a region is influenced by physical and chemical parameters that are strongly affected by natural processes such as water chemistry in the recharged area, water intermixing, groundwater recharge, aquifer discharge and recharge, water flow path.

The term emerging contaminants (ECs) is generally used to refer to compounds previously not considered or known to be significant in groundwater in terms of distribution and/or concentration, which are now being more widely detected and which have the potential to cause known or suspected adverse ecological or human health effects.ECs include perfluorinated compounds (PFCs), nanomaterials, pesticides, pharmaceuticals, industrial compounds, personal care products, fragrances, water treatment by-products, flame retardants and surfactants, UV-filtersas well as caffeine and nicotine. Because of their rapidly increasing use in industry, transport, agriculture, and urbanization, these chemicals are entering the environment at increasing levels as hazardous wastes and non-biodegradable substances.

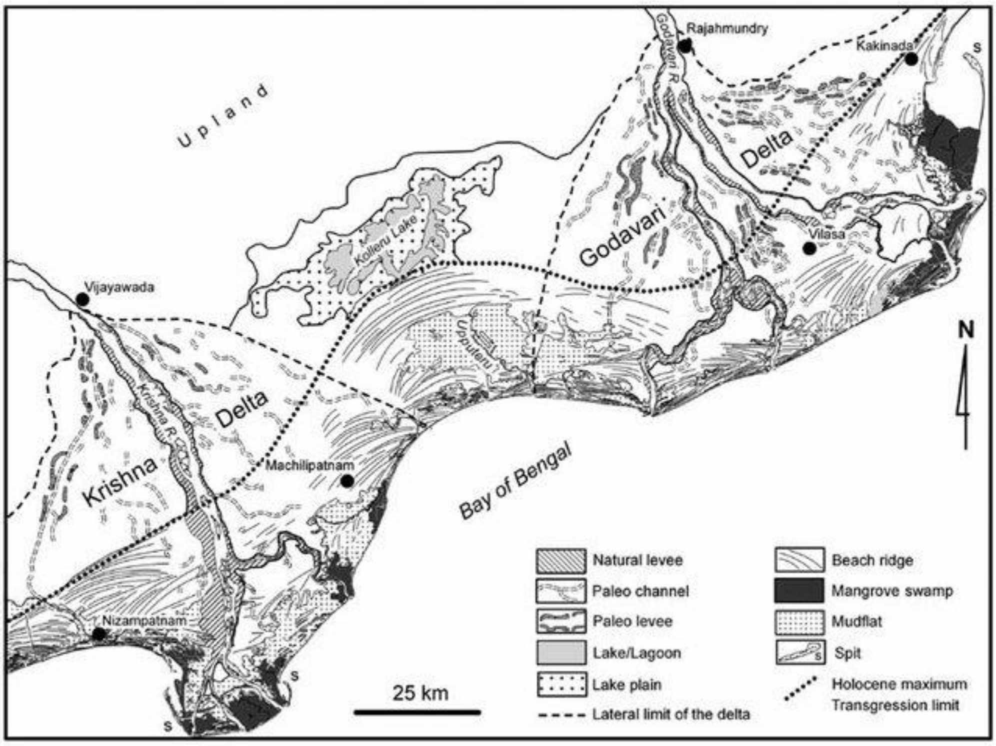


Fig. 1. Location map of Krishna Godavari deltaic region

The pathways through which these pollutants enter surfacewaters are well known and the main contributions are from effluents of wastewater treatment plants, where some residues are not removed,and from agricultural and industrial activities. Contacts and exchanges between the aquifers, rivers and sewage networks, and leaching fromagricultural fields, can cause the contamination of shallow and deepgroundwater. ECs may be a significant problem when surface and groundwaterare used for drinking water production because the conventionaldrinking water treatments, like treatment with active carbon, flocculation,and disinfection, are not specifically designed to remove these micropollutants. Traces of ECs in drinking water are actually measured and reported in only a few studies and the spatial and temporal variability of the majority of ECs in theenvironment is still poorly understood.

In view of the above, characterization of groundwater dynamics in Krishna-Godavari Deltasinterimshas been proposed using geochemical, Isotopes and emerging contamination and their sources and its impacts on human health for sustainable drinking water supply.

10. Approved Action Plan/Methodology

i) Collection of groundwater level data, lithological data, water quality data from published report, literature and from various govt. agencies.

ii) Hydrogeological characterization of the study area and establish specific linkages of groundwater quality with hydrogeology.

iii) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.

iv) Analysis on flow and movement of groundwater.

v) Analysis for physico-chemical parameters [pH, EC, TDS, Eh, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (Cl, SO_4, NO_3, HCO_3), minor elements (Fluoride, PO_4, NH_4)] metal concentrations (As, Fe, Mn, Cd, Zn, Cu, Cr, Pb, Co, Ni, Ba, Sr, V, Sc),and emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) in the collected water samples.

vi) Analysis of Stable environmental isotopes of Hydrogen and Oxygen in the collected water samples

vii) Processing of hydro-chemical data for pre- and post-monsoon seasons as per BIS and WHO standards to examine the suitability of ground water for drinking purpose.

viii) Ionic relationships will be developed and water types will be identified. Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking/ & irrigation water quality standards.

ix) Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.

x) Soil quality monitoring for metal concentrations (Zn, Cu, Cr, Co, Ni, Ba, Sr, V, Sc) in the petroliferous regions of the study area during pre- and post-monsoon seasons.

xi) Probable impact of emerging contaminants in groundwater on human health.

11. Approved Work schedule / Timeline

S. No.	Major Activities	2022-23				2023-24			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Data collection								
2	Field surveys &Sample collection								
3	Sample Analysis								
4	Data Processing								
5	Interim Report								
6	Final Report								

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Data collection	• Data collection is under progress.
2.	Field surveys &Sample collection	• Reconnaissance survey of the study area completed with identification of sampling sites. • Collection of groundwater samples from selected sources in pre-monsoon (May-June 2022) and post-monsoon (December 2022) season at identified locations has been

		completed with CGWB & RCK.
3.	Sample Analysis	• Analysis of physico-chemical parameters and metal concentrations in the groundwater water samples of pre-and post-monsoon season completed. • Analysis of emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) in the collected groundwater water samples of pre-monsoon season completed and of post-monsoon season is in progress. • Analysis of Stable environmental isotopes of Hydrogen and Oxygen in the collected groundwater samples has been completed.
4.	Data Processing	• Processing of data is under progress.

13. **Recommendation / Suggestion:**

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Prashant Rai, CGWB appreciated the proposed study and suggested that this is the right time to take up this study for the benefit of society.	--

14. **Analysis & Results:**

Field surveys &Sample collection

- Reconnaissance survey of the study area completed with identification of sampling sites.
- Collection of groundwater samples from selected sources at identified locations in pre-monsoon (June 2022) and post-monsoon (December 2022) season for physico-chemical parameters, metal concentrations and emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) has been completed with CGWB & RC Kakinada.

Sample Analysis

- Analysis of physico-chemical parameters using Ion Chromatograph and metal concentrations (As, Fe, Mn, Cd, Zn, Cu, Cr, Pb, Co, Ni, Ba, Sr, V, Se, Al, Hg, U, B)using ICP-MS in the groundwater water samples of pre-and post-monsoon season completed.
- Analysis of emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) in the collected groundwater water samples of pre-monsoon season using GC-MS/MS completed and of post-monsoon season is in progress.
- Data of physico-chemical parameters, metal concentration and emerging contaminants is under processing.
- Analysis of Stable environmental isotopes of Hydrogen and Oxygen in the collected groundwater samples has been completed.

15. **End Users / Beneficiaries of the Study:** Public Health Department, AP, Ground Water Department, AP, CGWB.

16. **Deliverables:** Technical report and research papers,

17. **Major items of equipment procured:** None

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH)

19. **Data procured or generated during the study:** Water quality data on Emerging Contaminants

20. **Study Benefits / Impacts:** The study will identify degraded groundwater quality zones, possible sources of pollution, understanding geochemical processes controlling the aquifer chemistry and will suggest the measures for sustainable groundwater supply for drinking purpose in the study area, therefore enable better planning and management of groundwater resources.

21. Involvement of end users/beneficiaries: CGWB

22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes

23. **Shortcoming/Difficulties:** None.

24. Future Plan:

i) Processing of hydro-chemical data for pre- and post-monsoon seasons for different designated uses.
ii) Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking/ & irrigation water quality standards.
iii) Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.
iv) Soil quality monitoring for metal concentrations (Zn, Cu, Cr, Co, Ni, Ba, Sr, V, Sc) in the petroliferous regions of the study area during pre- and post-monsoon seasons.

Study – 7 (Internal Study)

1. **Title of the Project : ** Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures

2. **Project Team**

Project Investigator	Dr. Rajesh Singh, Sc. D, EHD
Project Co-investigator	Dr. R. P. Pandey, Sc. G & Head, EHD Dr. Sumant Kumar, Sc. D, GWHD Dr. Pradeep Kumar, Sc. D, EHD Dr. M. K. Sharma, Sc. F, EHD Dr. V. K. Tyagi, Sc, D, EHD Dr. KalzangChhoden, Sc. C, EHD

3. **Type of Study:** Internal Study, **Budget:** Rs. 30.1 lacs

4. **Nature of Study:** Applied& Basic Research

5. **Date of start:** July 2021

6. **Scheduled date of completion:** June 2024

7. **Duration of the Study:** 3 Years

8. **Objectives**
   v) To determine the mechanisms governing the As mobility, and quantify the rate and extent of these reactions in order to develop a reactive transport model to predict As mobility in groundwater, and
   vi) To design alternatives to mitigate As contamination of drinking water

9. **Statement of the Problem**

Groundwater is the most important source of domestic water in the Haridwar district and is generally free of health hazardous contaminants, however, with increasing population and intensive agricultural practices, the groundwater is getting polluted resulting in the abiotic and biotic weathering reactions of primary and authigenic minerals containing As and other trace metals. The release of previously sequestered arsenic from soils and sediments is well-recognized to result in geogenic contamination of drinking water and presents significant health risks to human and other living organisms. Our recent study on 'Water Quality Assessment of Haridwar District' indicated higher As concentration in the groundwater of Laksar and Manglaur tehsil at few locations in the range 10 to 30 µg/l. Although, the As concentration were below maximum permissible limit of 50µg/lprescribed by BIS for drinking water, it exceeded the acceptable limit of 10 µg/l. Previously, As was reported in a location near Solani river which is a monsoonal river and in the non-monsoon the flow in the river is contributed through the untreated/partially treated domestic and industrial discharge. This clearly indicates the role of pollutants entering the aquifer and initiating the secondary reaction resulting on the release of As from the aquifer sediments and requires thorough investigation before it is too late. The identification of the factors responsible for the release of the As from the sediments will help in containing the As and reducing the associated health hazard risk to consumers.

Keeping in view of same, the study aims at analyzing the groundwater and sediment samples for their As content and other parameters. Efforts will be also made to identify the factors responsible for the release of As from the sediments through batch/column experiments.

10. Approved Action Plan/ Methodology:

iv) Thorough review of abiotic and biotic geochemical mechanisms known to contribute to As mobility in aquifers and determine the groundwater constituents or parameters influencing As mobility.
v) Collection and characterization of the groundwater samples from and in the vicinity of identified locations with higher As concentration.
vi) Characterization of the aquifer sediment and As mobility in the aquifer where As was observed in exceeding the prescribed drinking water limit.
vii) Batch and column experiments for identifying the factors responsible for As mobilization.
viii) Develop a model to identify As mobility in groundwater.
ix) Design alternatives to mitigate As contamination of drinking water.

11. Timeline (Approved):

Sr. No.	Major Activities	2021-22			2022-23				2023-24				2024-25
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
1.	Field Investigation and sampling plan												
2.	GW sample collection and analysis												
3.	Aquifer sediments collection and characterization												
4.	Batch & column experiments												
5.	Model development for As mobility												
6.	Alternatives to mitigate As												
7.	Publications												
8.	Interim Report												
9.	Final Report												

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Samples are collected from the selected locations. • Analysis for organoleptic, major ions, and coliforms in the collected samples completed. • Analysis of trace metals is in progress.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	No specific comments	--

14. Analysis & Results:

Field Investigation and sampling plan

- Sampling locations were selected considering the identified location with high As concentration in the groundwater.

Sampling & Analysis

- The handpumps, which are being used extensively, of the identified villages were continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017). Samples were also collected from the deep wells as per availability.
- The organoleptic parameters, major ion, and bacteriological analysis completed for all the samples following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017). Trace metal analysis is under progress.

15. End Users / Beneficiaries of the Study: Policy makers and planners of State/Central Government Organizations

16. Deliverables: Technical report and research papers, Factors impacting As mobilization, Model to identify As mobility, and alternatives for As mitigation.

17. Major items of equipment procured: Glove bag/anaerobic chamber will be procured for conducting experiments.

18. Lab facilities used during the study: Water Quality Laboratory (NIH)

19. Data procured or generated during the study: Water quality data of the study area and As mobilization mechanism

20. Study Benefits / Impacts:

The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the information on the factors impacting As mobilization in the groundwater. The alternatives for As mitigation will be also suggested which can be implemented by concerned departments of UK government.

21. Involvement of end users/beneficiaries: None

22. Specific linkage with Institution and /or end users / beneficiaries: Yes

23. Shortcoming/Difficulties: None.

24. Future Plan:

- Collection and analysis of GW and aquifer sediment samples.
- Batch and column experiments.
- Procurement of glove bag/anaerobic chamber.

Study - 8 (Internal Study)

1. **Title of the Study:** Simulation of Non-Point Source Pollution Processes in Song River

2. **Study Group:**

Project Investigator	Dr.Pradeep Kumar, Sc. 'D', EHD
Project Co-investigator	Dr. M. K. Sharma, Sc. 'E', EHD Dr. Rajesh Singh, Sc. 'D', EHD Er. R. K. Nema, Sc. 'B', EHD
Scientific Staff	Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA Mr. Rakesh Goyal, Tech. Gr. I

3. **Type of Study:** Internal Study**, Budget:** Rs. 43.02 lacs
4. **Nature of Study:** Applied Research
5. **Date of start:** Nov 2019
6. **Scheduled date of completion:** Oct 2023
7. **Duration of the Study:** 4 Years

8. **Study Objectives**
   (i) Assessment of the point and non-point pollutant loads
   (ii) Mapping of various non-point pollution sources
   (iii) Simulation of various hydrological processes in the river catchment
   (iv) Simulation of non-point source pollution process for sediment, nutrients and pesticides in the river catchment

9. **Statement of the Problem:**

Increasing population and subsequently increasing water, food and energy demands have put tremendous pressure on the water resources. The problem is more substantiated by the increasing consumption of the products with high water footprints. The food and energy demands of rapidly increasing population have caused intense agriculture, industrialization and urbanization. This has resulted in indiscriminate discharge of municipal and industrial wastes. Municipal wastes being biodegradable produce a series of directional but predictable changes in water bodies. Industrial effluents are responsible for pollution to a lesser extent but the effects produced by them may be more serious as nature is often unable to assimilate them. Agriculture is also responsible for degrading the water quality through leaching and runoff from agricultural fields and animal husbandry units, which contain predominantly organic compounds from the use of mineral fertilizers and chemical pesticides. These pollutants ultimately contaminate aquifer system due to surface and groundwater interactions.
The planning of water as a national resource is not merely a question of ensuring the availability of water in the right quantity at the right time for diverse purposes, but also ensuring the right quality for the intended use. Further, for any proper water resources planning, whether long or short term, before going into alternative plans for development, it is very essential to assess water quality problems together with hydrological analysis.

Since, point source pollution meets the river at known locations, it may be addressed by STPs or ETPs. Non-point source pollution reaches the river through the landscape after following a number of hydrologic, physical, chemical and biological processes. Hence, it is very complex to assess the causes and plan for its remediation. Very few assessments of non-point source pollution have been made in Indian rivers and they are mostly limited upto quantification of pollutant loads through the flux balance approach. Therefore, this study is being envisaged to simulate the non-point pollution process in a lower Himalayan catchment to identify the sources and causes of non-point source pollution.

10. Approved Action Plan/Methodology:

(i). Procurement of secondary data required for the analysis from various govt. agencies (discharge, sediment, other water quality parameters, soil map etc.)

(ii). Collection of water samples at monthly frequency during non-monsoon and daily frequency during monsoon season from selected locations of Song river

(iii). Collection of data on usage of fertilizers and pesticides in the Song river catchment.

(iv). Analysis of water samples for general water quality parameters, total suspended solids, nutrients and pesticides

(i). Hydrological and water quality modelling using SWAT model

11. Timeline:

S. No.	Major Activities	2019-20		2020-21				2021-22				2022-23				2023-24		
		3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr
1	Literature survey																	
2	Reconnaissance visit and sampling plan																	
3	Secondary data collection																	
4	Field surveys																	
5	Sample Collection and Analysis																	
6	SWAT Model: Preparation of database																	
7	SWAT Model: Calibration, Validation & Simulation																	
8	Interim Report																	
9	Final Report																	

12. Objectives and achievement during last twelve months:

S. No.	Objectives	Achievements
(i)	Assessment of the point and non-point pollutant loads	Three sites have been selected for the assessment of point and non-point source pollutant loads. The water quality sampling and discharge monitoring at these three sites have been carried out on weekly basis during the monsoon season, and monthly basis during the non-monsoon season. Further, samples have been analyzed for the water quality parameters.
(ii)	Collection of data on usage of fertilizers and pesticides in the Song river catchment	The village level surveys are being conducted for collection of data on usage of fertilizers and pesticides.
(iii)	Simulation of various hydrological processes in the river catchment	The preliminary SWAT model set-up has been completed using the secondary data sources (freely available web sources). Discharge data from CWC and soil maps from NBSS&LUP have been obtained and the same have been used for the analysis.
(iv)	Simulation of non-point source pollution process for sediment, nutrients and pesticides in the river catchment	The model set-up for simulation of non-point source pollution processes will be carried out only after the primary data of discharge and water quality is collected.

13. Recommendation / Suggestion:

S. No.	Recommendation / Suggestion	Action Taken
1.	No comments	--

14. Analysis & Results:

Three sites in the Song catchment have been selected for simulating non-point source pollution processes through the SWAT model. The first site selected is the CWC G&D site at Satyanarayana. Suswa is a major tributary of Song river and it meets Song river few kilometers upstream of Satyanarayana G&D site. So, the second site has been selected on Suswariver just before its confluence with Song river. Another site on the Song river have been selected in the upstream of the confluence of Song and Suswa rivers. These sites have been selected to isolate the point and non-point sources of pollution. Although sampling was planned to be started during monsoon season of 2021, but, due to uncertain travel restrictions caused by Corona pandemic, the same could be started from Jun 2022.

15. End Users / Beneficiaries of the Study: Deptt. of Irrigation &Deptt. of Agriculture, Uttarakhand

16. Deliverables: Technical report and research papers

17. Major items of equipment procured: None

18. Lab facilities used during the study: Water Quality Laboratory (NIH)

19. Data procured or generated during the study: Water quality data of the area

20. Study Benefits / Impacts:

The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the various sources of point and non-point pollution and will suggest various scenarios for mitigating these impacts. The research outcomes from the study will be as follows:

a. Point and Non-Point pollutant loads at various locations in Song river
b. Quantum of non-point source pollution for various scenarios of fertilizers/ pesticides applications
c. Technical report and papers

21. Involvement of end users/beneficiaries: None

22. Specific linkage with Institution and /or end users / beneficiaries: Yes

23. Shortcoming/Difficulties: None

24. Future Plan:

i) Collection and analysis of samples (monthly sampling during non-monsoon and daily sampling during monsoon) from three selected sites in the Song catchment.
ii) Procurement of discharge data from CWC for the current period i.e. 2021-2023.
iii) SWAT Model calibration and validation both for flows and for water quality.

Study – 79(Internal Study - New)

1. **Title of the Project:** Hydrological Studies for the Conservation of Rewalsar Lake

2. **Project Team**
   - **Project Investigator:** Dr. Kalzang Chhoden, Sc. C, EHD
   - **Project Co-investigator:** Dr. Rajesh Singh, Sc. D, EHD
     Dr. R. P. Pandey, Sc. G & Head, EHD
     Dr. Pradeep Kumar, Sc. D, EHD
     Dr. Vinay Kumar Tyagi, Sc. D, EHD
     Er. Omkar Singh, Sc. G, RMOD
     Dr. Shuhas Khobragade, Sc. G, HI
     Dr. D.S. Malik, Professor, GKU, Haridwar

   In Collaboration with HPSWA, Shimla

3. **Objectives**
   a) Identification of morphological features of the lake.
   b) To understand the hydrological characteristics.
   c) To identify the causes of fish mortality and eutrophication status of lake.
   d) To Assess the rate of sedimentation.
   e) Suggestions for remedial measures for pollution abatement
   f) Mass awareness and outreach activity.

4. **Present state-of-art**

Lakes are one of the most important inland freshwater resources for meeting the increasing water demand. Lakes supply water for drinking, irrigation, fisheries, etc., and thus lakes have significant economic and recreational value. In Lake Ecosystem, water quality depends upon physical, chemical, and biological factors. Mainly lakes have five major problems: lowering water level, siltation, acidification, toxic contamination, and eutrophication. Phytoplankton dynamics influence the trophic level and portability of water for human use. Today surface water is most vulnerable to pollution due to its easy accessibility for disposal of pollutants and wastewaters. During the last decade, widespread deterioration in water quality of inland aquatic ecosystem systems has been reported due to the rapid development of industries, agriculture, and urban sprawl. Lakes also help in recharging groundwater and attaining water security. In view of the spatial and temporal variations in the hydrochemistry of surface waters, regular monitoring programs are required for reliable estimates of the water quality. Water quality monitoring is a helpful tool not only to evaluate the impacts of pollution sources but also to ensure efficient management of water resources and the protection of aquatic life.

Previous studies reported the effect of change in land use and seasonal variation onlake water quality. A study on Pandoh lake indicate the enrichment of nutrients in the lake water(Anshumali and Ramanathan, 2007). Kumar et al., 2019 reported hypereutrophic condition of Renuka Lake based on the Carlson's indexdue to the presence of a high concentration of nutrients. A study by Kasaya (2015) on the Rewalsar lake reported high concentrations of BOD, COD, Cl, phosphate, sulphate and very low transparency.Another study (Jindal et al., 2014) revealed the phytoplankton dynamics and water quality status of Prashar Lake. Based on the Carlson's trophic status, the lake was classified as oligotrophic with TSI values 17.085 (2008-09) and 14.57 (2009-10). Relatively less abundance of Cyanophyceae and high percentage of desmides in the lake water indicated oligotrophic status of lake. *Paenilbacillus inbetae sp*ecies a cold adapted antimicrobial producing bacteria was isolated from high altitude Suraj Taal lake by Kiran et al., 2017. Major ion chemistry of Renuka lake have been studied and it was observed that shale slate, sandstone, quartzite, and limestone rocks have contributed to the ion chemistry of lake water (Choden et al., 2022; Das and Kaur, 2001). However, the reaction of carbonate to sulphuric acid as a proton source during weathering process in the basins accounts for the high concentration of sulphate content in water. Kumar et al., 2006 and Singh et al., 2008 further reported the eutrophic conditionsof Himalayan lakes using phosphate data. The results showed

Mansar, Surinsar and Tsomoriri under eutrophic condition and Dal, Tsokar and Renuka Lake under hyper eutrophic condition. Furthermore, siltation is the another major problem in lakes due to the human and other interferences. Sedimentation is one of the main problems that reduces the depth and size of lakes. The sedimentation rate in each lake differs due to catchment lithology, slope, vegetation cover, and silt transport through inlet stream, rainfall, and wind causing differential erosion.

As per the Himachal Pradesh State Wetland Authority (HPSWA), Rewalsar lake is presently facing problems related to water quality, fish mortality, and siltation. Rewalsar wetland ecosystem is at the critical stage of deterioration mainly due to water pollution and siltation in the water body. Increasing tourism activity and human settlement around the lake create hydrological and ecological distresses. In addition to this, frequent incidents of high fish mortality in the water body due to increasing water pollution has been observed. An increase in nutrient levels in lake from the various non-point sources also leads to eutrophic conditions. Keeping this in view and as suggested by the HPSWA, a systematic and comprehensive study on the hydrological investigation of Rewalsar Lake has been proposed.

5. Study Area:

Rewalsar is a natural wetland and is located in district Mandi of Himachal Pradesh at a distance of 24 km in the southwest direction of Mandi on the Mandi-Hamirpur highway at the height of 1360 m. The lake is shaped like a square with a shoreline of about 735 m. This area falls on the confluence of "Sikandara-Dhar and 'Barkot' ranges of sub-mountainous Himalaya between latitude 31°37'30" N and E. 76°49" E longitude. The place has a series of small beautiful lakes, of which Rewalsar lake is the most beautiful and sacred. The total catchment area of Rewalsar wetland is 173 hectares. The main source of water for the Rewalsar wetland is its internal water springs. Rewalsar is an important tourist destination and also one of the most famous sacred spots for Hindus, Buddhists, and Sikhs as it is largely associated with serpent worshipping. Keeping view of its religious, cultural, and ecological importance, the Ministry of Environment & Forests, GoI has declared the Rewalsar wetland under the National Wetland Conservation Programme.

The climate of the area is sub-tropical monsoon type. The average precipitation at Rewalsar is 1690 mm and the average maximum temperature is 33° C. The minimum temperature touches the freezing point and sometime snowfall occurs in the area. Broadly, four distinct seasons namely, winter (middle of December to February), summer (March to June), monsoon (early July to the middle of September), and autumn (October to November) is observed in Rewalsar. Winter is mild in low-lying areas, whereas it snows on high mountain ranges. The spring season is warm andsunny,and the monsoon season is the wettest part of the year and is characterized by high humidity. Summers are prickly hot. The area is mostly hilly. The catchment's lithology is composed of middle Siwalik Group (Pliocene) rocks comprising predominantly of fine grained, light colored sandstone with gray siltstone, and shale inter-layered. The latter two are often thicker than the former, indicating intermittent subsiding basin condition, their more weatherable nature and intense tectonic activity; sandstone layers occasionally stand out as resistant boulder within the weathered mass. The greenish gray-siltstone often show spheroidal or elephant skin weathering which weathers to soil. Fine specks of mica are seen in the siltstone. Clayey soil is also common and is not very deep. The major, trace and rare earth element (REE) geochemistry of Rewalsar Wetland sediments supported by petrographic. Clay mineralogical studies have revealed that sediments have been derived from metamorphic source terrain. In the very vicinity of the wetland area, sandstone is seen dipping into the hill in northwest direction. The depression formed for the accumulation of water appears to have been caused by a strike slip fault that runs in the NE-SW direction. On the whole, the rocks are soft and the strata are unstable, easily lending to the forces of denudation and erosion.

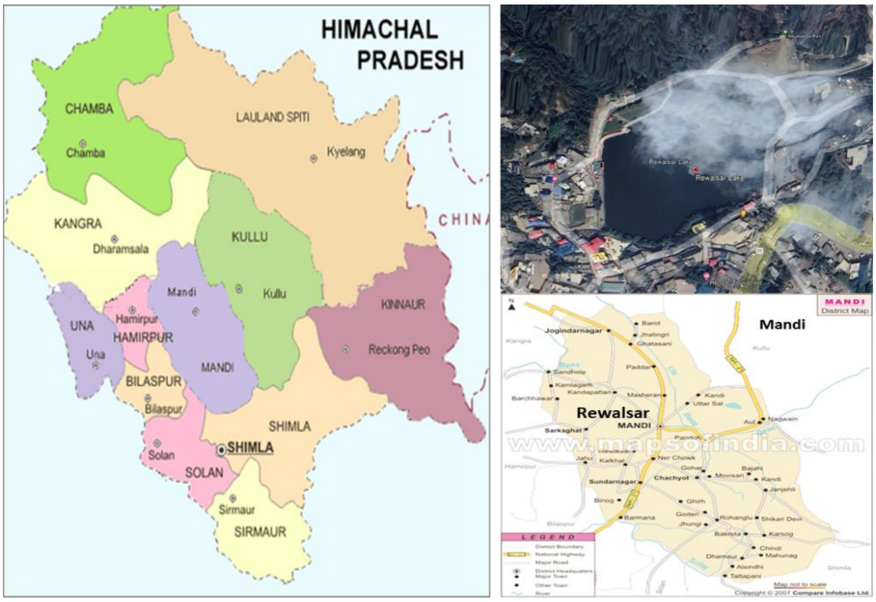


Figure: Study Area

6. Methodology:

Research objective wise detailed methodology is given below:

a) Objective 1: Preliminary study will be carried out to identify the physical features of lakes and sources of water in the lake considering the type of plantation, population, etc. Collection of baseline data of area related to morphological and geographical data. Sampling sites will be identified using GPS and sampling sites will be marked for further sampling and source identification of lake water. Seasonal and temporal water sample collection from the study area.

b) Objective 2: The water balance study of lakes will be carried out by calculating the inflow and outflow to/from the lake. The water quantity of lake will be measured by using the following equation:

$$\Delta S = Is + Iu + Pi - Qs - Qu - Ei$$

Where ΔS= Change in lake storage
Is=Surface inflow
Iu= Underground Inflow
Pi=Inflow due to direct precipitation
Qs= Surface outflow & withdrawal
Qu= Underground Outflow including seepage
Ei= lake evaporation

Table 1: Parameters to be investigated in the field

Parameters	Instrument used
Surface Water inflow/outflow	Discharge flow meter with data logger
Groundwater inflow/ outflow	-
Precipitation	Rain gauge with data logger
Evaporation	Pan method/ Observatory data
Depth (D)	Water level recorder
Transparency	Secchi Depth

c) **Objective 3:** The samples will becollection at different time intervals**.** Collected samples will be analyzed in the laboratory for physico-chemical and biological parameters (Table 2).

The accumulation of nutrients in the lake will be assessed by using the following equation:

$$\Delta N = (Sin + DRin + GWin + RDin) - (Sout + GWout)$$

Where ΔN= Change in nutrient stored in the lake
Sin=Nutrient input to lake via stream flow
DRin =Nutrient input to lake via direct runoff
GWin= Nutrient input to lake via groundwater
RDin=Nutrient input to lake via direct rainfall
Sout= Nutrient outflow from lake via lake opening, stream discharge
GWout=Nutrient outflow from lake via seepage through the beach barrier & to groundwater

Moreover, water samples will be identified for phytoplankton and chlorophyll content. The different indices will be calculated by using different equations:

i. Trophic Status Indices

Carlson's trophic status index (Carlson, 1977) has been widely used to estimate the trophic condition of water bodies. This method is based on three parameters namely Chl-a, SD and TP in a water body. Kratzer and Brezonik (1981) concluded that the total nitrogen (TN) content of the water body also impacts productivity and incorporated TN in the composite trophic status index (CTSI).

$$CTSI = \frac{TSI\ (SD) + TSI\ (Chl - a) + TSI\ (TP) + TSI\ (TN)}{4}$$

Where: TSI (SD) = 60-14.41 ln(SD)
TSI(Chl-a) =9.81 ln(Ch.-a) +30.6
TSI(TP)=14.42 ln(TP)+4.15
TSI (TN)=14.43 ln(TN)+54.45

TP and Chl-a are in µg/l, and SD transparency in meters. Based on the values of CTSI, the ponds are classified as oligotrophic, mesotrophic, eutrophic, and hypertrophic.

ii. Nygaard's algal index: Nygaard's index (1949) evaluates the productivity of water bodies based on the ratios of different algal groups. The combination of four indices is used to calculate a Compound Quotient Index (CQI)

$$Cyanophycean\ index = \frac{Cyanophyceae}{Desmidaceae}$$

$$Chlorophycean\ index = \frac{Chlorococcales}{Desmidaceae}$$

$$Bacillariohycean\ index = \frac{Centric\ diatom}{Pennate\ Diatoms}$$

$$Euglenophycean\ index = \frac{Euglenophyceae}{Cyanophyceae + Cholorococcales}$$

$$CQI = \frac{Cyanophycea + Chlorophyceae + Bacillariophyceae + Euglenophyceae}{Desmidaceae}$$

iii. **Shannon-Wiener diversity index**: Shannon-Wiener Index (H) accounts for both abundance and evenness of species present and is commonly used to characterize the species diversity in a community (Shannon and Weaver, 1964). The following equation is used to calculate the Shannon-Wiener Index:

$$H = \sum[\ (pi).ln\ ln(pi)]$$

Where pi =is the proportion of individuals of one particular species observed divided by the total number of species.

Table 2: Parameters to be analyzed in laboratory

Parameters	Instrument used
pH, EC, TDS	Sensor based Multiparameters
DO,BOD,COD	Titration method
NO3, NO2, O-PO4, SO4, NH3, Ca, Mg, Na, K, Cl	Ion chromatography
HCO3	Titration
Total Nitrogen	TKN analyzer
T-PO4, Chl a,b,c	Spectrophotometry/Sonde
Planktons density quantity	Microscope
Trace Metals	ICPMS
Pesticides	GCMS
Total organic carbon (TOC)	TOC Analyzer
TC/FC	Field test kit (Bactaslyde/Colilert)

d) **Objective 4:** Rate of sedimentation in the lake will be estimated using conventional/radiometric dating techniques.

e) **Objective 5:** Based on the result, remedial measures will be formulated to improve the water quality and quantity of lake.

f) **Objective 6:** Mass awareness activities will be carried out with the involvement of stakeholder departments.

7. Research Outcome from the Project:

a) Water quality and eutrophication status of the lake ecosystem
b) Hydrological characteristics of lake.
c) Rate of sedimentation in the lake.
d) Remedial measure for water quality improvement
e) Research papers/ report

8. Cost Estimate

a. Total cost of the project : 53,16,000
b. Source of funding : NIH internal
c. Sub head-wise abstract of the cost:

Sr. No.	Sub-Head	1st Year	2nd Year	3rd Year	Total
1	Manpower (Resource Person Jr.-2 nos)(30,000+HRA)	792000	792000	792000	2376000
2	Travelling expenditure	300000	400000	300000	1000000

3	Infrastructure / Equipment / Consumable	1500000	70000	70000	1640000
4	Experimental charges	50000	50000	50000	150000
5	Misc. Expenditure	50000	50000	50000	150000
	Grand Total	2692000	1362000	1262000	5316000

d. Justification for sub-head-wise abstract of the cost

- Travelling expenditure: For visit to the study area, attending conferences, data collection, surveys, etc.
- Equipment/Consumables: Flowmeter, Water level recorder, Rainguage, chemicals, glasswares, plastics, electrodes, etc.
- Experimental charges: Towards the analysis of samples

9. Work Schedule

a) Probable date of commencement of the project : Dec. 2022

b) Duration of the project : 3 Years

Stages of work & milestone

S.N.	Work Element/ Milestone	1st Year				2nd Year				3rd Year			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Literature Review and Reconnaissance survey	■											
2	Hiring of project staff, equipment purchasing/installation	■	■										
3	Water Mass balance assessment		■	■	■	■	■	■	■				
4	Assessment of water quality and eutrophication status		■	■	■	■	■	■	■	■	■		
5	Estimation of rate of sedimentation			■	■	■	■	■	■	■	■	■	
6	Remedial measures								■	■	■	■	
7	Outreach activity				■				■				■
8	Interim Report/Publications				■				■				
9	Final report submission												■

10. Contribution of PIs

PIs	Contribution
Dr. Kalzang Chhoden Sc. C, EHD	Water Quality, Nutrient Balancing, Eutrophication Status of Lake, Identification of Morphological Features of Lake
Dr. R.P Pandey Sc. G & Head, EHD	Water Balancing Study
Dr. Rajesh Singh Sc. D, EHD	Water Quality and Nutrient Balancing Study
Dr. Pradeep Kumar Sc. D, EHD	Hydrological Investigation and Characteristics
Dr. Vinay Kumar Tyagi Sc. D, EHD	Water Quality & Remediation Measures
Dr. Omkar Singh Sc. G (RMOD) and Dr. Suhas Khobragade Sc. G, HI	Over all Lake Expert& Sedimentation Estimation
Dr. D.S. Malik, Professor, GKU, Haridwar	Fishery Expert
HPSWA, Shimla	Mass Awareness and Outreach Activity

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Study – 10 (Internal Study)

a) Title of the Project:
"Comprehensive evaluation of disinfection units of STPs in Ganga basin: Occurrence and control the formation of emerging oxidation precursors"

b) Name and Designation of the Principal Investigator:
Dr. Vinay Kumar Tyagi, Scientist D, NIH Roorkee

c) Name and Designation of the Co-investigators:
IIT Roorkee
Dr. Bhanu P Vellanki, Professor
Dr. A. A. Kazmi, Professor

NIH Roorkee
Dr. Rajesh Singh, Scientist D
Dr. Mukesh K. Sharma, Scientist F
Dr. Pradeep Kumar, Scientist D
Er. J. P. Patra, Scientist D
Dr. Kalzang Chhoden, Scientist C
Dr. R.P.Pandey, Scientist G

d) Duration of the Project : 3 years

e) Total amount of assistance required: Rs. 7366000
(Seventy three lakhs sixty six thousands rupees)

1. ORIGIN OF THE PROPOSAL

Chlorine is one of the most common chemicals used as disinfectant globally since it possesses all satisfactory properties suitable for treating both potable and treated wastewater. The efficiency of chlorination at sewage treatment plants (STPs) with similar effluent characteristics might vary due to the presence of variable organic compounds such as saturated, unsaturated, or polycyclic compounds. In Indian STPs, the chlorine doses varies from a low concentration of 2 mg/L to as high as 10 mg/L. Thus, the nature of the treatment process affects the efficiency of chlorination and also formation of emerging oxidation precursors (EOPs). Oxidation of organic matter results in the formation of undesirable oxidation byproducts, i.e., emerging oxidation precursors (EOPs), with the highest concentration being trihalomethanes (THMs) and haloacetic acid (HAA), followed by other EOPs such as N-nitrosodimethylamine (NDMA), chloramines, etc. The principal means for controlling the formation of EOPs is to avoid the direct addition of free chlorine and proper O&M of the treatment process. Discharge of the treated water into natural water deficit water bodies, or where the flow rate is significantly less, results in a spike in EOPs concentrations. Accumulating EOPs in natural water bodies has been shown to cause serious environmental hazards even at very low concentrations. In addition, anthropogenic activities in water bodies add up the organic matter load, leading to the formation of intermediates due to the presence of free chlorine in the effluent from treatment plants. Organic compounds that comprise BOD, TOC, and COD exert chlorine demand, and other disinfectants are directly proportional. Ammonia reacts with chlorine to form chloramines. Oxidation of nitrite results in the formation of NDMA. Thus, the formation of EOPs is of great concern, and evidently, there is a need for effective technical efforts. The prime focus of the proposed study is to investigate the performance of disinfection units of various sewage treatment plants in the Ganga basin for physico-chemical and microbiological properties, tracer studies, EOPs formation, and characterization (Trihalomethanes, THM; Halo acetic acid, HAA; Nitrosodimethylamine, NDMA), and propose a technical solution to control and remove the EOPs.

2. REVIEW OF THE STATUS OF RESEARCH AND DEVELOPMENT IN THE SUBJECT

The disinfection in a water system is the process to inactivate the pathogenic microorganisms to prevent the diseases caused by them. As chlorine is effective and easily available low-cost disinfectant used in the disinfection units of many STPs for discharge into streams in most part of the world, including India. It results in the production of EOPs (Trihalomethanes (THMs), Haloacetic acids (HAAs))due to the reaction with organic matter present in wastewater, leading to unfavorable health effects like cancer induction and adverse pregnancy outcomes (Plewa and Wagner 2015).

Concerns and awareness have been raised regarding the occurrence and toxicity of these EOPs and the pressing need for their removal after the presence reported from various developed countries like America(Krasner et al., 2006), Canada, China(Feng et al., 2019) and Europeancountries(Evlampidouet al., 2020) intheir treated water(Dodds et al., 1999,Villanueva et al., 2004, Lakind et al., 2010). After consuming these EOPs in any form approximately 2-17% of cancer cases reported by the USEPA(USEPA, 2006).

In India EOPs were reported from effluent of an atomic power station in Kalpakkam, TN, India (2013-2017) in 2019(Padhi et al., 2019a). Padhi et al. 2019b,also studied the formation of EOPs during the chlorine and chorine dioxide dose on treated water. Various other researchers also identified the EOPs in drinking water treatment plants (Kumari& Gupta, 2018) and sewage water treatment plant (Tak& Kumar, 2017) from India. The EOPs formation potential in River Ganga was also reported (Naladala et al., 2018, Mishra & Dixit, 2012, Mishra & Dixit, 2013). In one of the study between 2000-2007 the higher levels of trihalomethane formation potential (THMFP) were identified in national capital Delhi (Hasan et al., 2010). Thacker et al. 2002 in their study also evaluate the EOPs in drinking water treatment plants from Mumbai in different seasons from 1995-1996 and found the concentration exceed the guideline value of 200 µg/L in post monsoon season. Basu et al. (2011) also investigated EOPs concentration and cancer risk assessment for tap water samples from water treatment plants.

The United State Environmental Protection Agency (EPA) regulate over 700 EOPs identified by various researchers. Commonly four types of THMs (Chloroform ($CHCl_3$), Bromodichloromethane ($CHCl_2Br$), Dibromochloromethane ($CHClBr_2$) and Bromoform ($CHBr_3$) and three type HAAs (Monochloro-, dichloro-, and trichloroacetic acid (MCAA, DCAA, and TCAA), Monobromo-, dibromo-, and tribromoacetic acid (MBAA, DBAA and TBAA) and Bromochloro-, bromodichloro-, and dibromochloroacetic acid (BCAA, BDCAA and DBCAA)) are identified (Tak et al.,2020).

3. PROJECT JUSTIFICATION (NEED FOR STUDY)

Humans have been exposed to the undesirable EOPs through various routes such as dermal, inhalation, and ingestion. These EOPs are designated as probable human carcinogens and are known to adversely impact the reproductive system (Nieuwenhuijsen et al., 2000; US EPA). Therefore it is important to remove the EOPs from the water before the discharge in a water body or before the release in the water distribution system.

In India very few studies taken into account to study the fate of EOPs formation in disinfection units of water/wastewater treatment systems. Few studies has been conducted on water sample collected from Ganga's barrage water treatment plant in Kanpur, India. They report that THMs concentration was within limit according to WHO guidelines(Mishra and Dixit 2012; Mishra and Dixit 2013). Kumari and Gupta (2018) studied THMs in drinking water samples of eastern India and found THMs concentration between 231 to 487 μg/L , which were very higher than the suggested limit of 80 μg/L by United State Environmental Protection Agency (USEPA).Naladala et al (2018) also reported HAA formation in ganga river.

There is inadequate information regarding EOPscharacterization in the disinfection units of STPs. A comprehensive nationwide STPs investigation program is required forEOPscharacterization based on the critical control design parameters of secondary treated wastewater. These parameters are chemical oxygen demands (COD), biochemical oxygen demand (BOD),Humics,total suspended solids (TSS), pH, alkalinity, ammonia, nitrite, nitrate and pathogens etc. Moreover, Cl_2dose,contact time, seasonal temperature alsoplay a significant role in EOPs formation.

Coagulation with alum and ferric sulphate, ozonation, adsorption through activated carbon, magnetic ion exchange, UV/ H_2O_2 and nanofiltration have all been used to remove the EOPs. These techniques have been selective in removing certain EOPs (Chaukura et al., 2020). However, integration of an advanced treatment unit after disinfection unit for EOPs removal may add further capital and operational cost in the treatment system. Therefore, it seems feasible to remove the residual organics and nitrogen precursors before biologically treated wastewater enters into the disinfection unit. In this way, formation of EOPs could be prevented. Thus, we proposed some low cost solutions of activated carbon, biochar and biological activated carbon (BAC) processes for removal of residual organics and nitrogen precursors. It will provide the new insights on the effective control onEOPs formation in disinfection units.

Based on the literature survey, it is observed that limited information is available on the characterization of EOPs in chlorinated sewage in India. Once this characterization data available from various sewage treatment plants in India, it will be easier to propose best suited control measures for EOPs formation to the Government of India. Hence, the proposed study aims to comprehensively characterize the EOPs from chlorine disinfection unitsand recommend best EOPs management options in Ganga Basin forsafe effluentdischarge into stream. The findings can be the stepping stone in the development of EOPs characterization and achieve the sustainablemanagement practices.

4. OBJECTIVES

The specific objectives of this study are:

1. To study the pathogen removal efficiency of chlorination system in full-scale sewage treatment plants.
2. To study the factors affecting chlorinationefficiency [dose, contact time, treated effluent quality, temperature, hydraulics, types of pathogens etc.,]
3. To study the formation of Emerging Oxidation Precursors (Qualitative and quantitative)in disinfection units of full-scale treatment plants.
4. To study the impact of chlorinated water discharge on water quality of receiving water body
5. To conduct pilot-scalestudies for the removal of residual organics and nitrogen precursors and control the formation of EOPs in chlorination system
6. To suggest the optimal chlorine dose w.r.t secondary treated effluent to achieve effective pathogens removal and control EOPs formation.

5. METHODOLOGY

5.1.List of Sewage treatment plants (STPs)

Twelve sewage treatment plants (STPs)representing different climates and topographies installed by the municipalities and other government bodies in various cities of Ganga basin were selected for study (Table 1). The plants use different technologies according to wastewater type, fund availability, governing body suggestions, and effluent requirements etc.

Table 1. List of the selected STPs for the study

S. No.	Name of STP	Capacity (MLD)	Technology	Wastewater	Disinfection type
1.	New Tehri, Garhwal	5	Extended Aeration	Sewage	Chlorination
2.	Kargi, Dehradun	68	SBR	Sewage + Septage	Chlorination
3.	Lakkarghat, Rishikesh	26	SBR + Filtration	Sewage	Chlorination
4.	Chorpani, Rishikesh	3.5	MBBR +Filtration Process	Sewage	Chlorination
5.	Jagjeetpur, Haridwar	27	Primary Clarifier + SBR + Filtration	Sewage	Chlorination
6.	Chandreshwar Nagar, Rishikesh	7.5	MBBR + Disk Filtration	Sewage	Chlorination
7.	IIT Roorkee	3	SBR process	Sewage	UV
8.	Coronation Pillar, Delhi	318	A_2O process	Sewage	Chlorination
10.	Indrapuram, Ghaziabad	56	SBR	Sewage+Industrial wastewater	Chlorination
11	Dinapur, Varanasi	140	Conventional Activated Sludge Process	Sewage	Chlorination
12	Goitaha STP, Varanasi	120	SBR	Sewage	UV

5.2. Performance evaluation ofdisinfection units

5.2.1. Efficiency of disinfections units

Waste water samples will be collected from various stages of STPs, i.e., raw wastewater (STP inlet), biologically treated wastewater (inlet of disinfection unit) and finally treated wastewater (disinfection unit effluent). The collected water samples will be characterized for various physical-chemical and microbiological parameters.

(v). Physical-chemical parameters: COD, BOD, DOC, bDOC, TOC, TSS, pH, alkalinity, ammonia, nitrite, nitrate, residual chlorine, humic substances

(vi). Indicator organisms and pathogens: Total Coliforms, FecalColiforms, E.Coli, Shigella, Salmonella

5.2.2. Factors affecting disinfection efficiency

The effects of various factors on disinfection efficiency (indicator microbes & pathogens removal) and EOPs formation will be studied comprehensively. Key factors will be taken into account: Disinfectant contact time, concentration/dosage of disinfectant, temperature, types of pathogens and indicator organisms, effect of water quality (suspended solids, organic matter), hydraulic retention time (HRT) of disinfection units (tracer study, designed and actual HRT verification), Cl_2 decay (Figure 1)

Fig. 1. Chlorine decay and microbial (pathogens and indicators) concentration along the chlorination disinfection units

5.2.3. Quantitative and qualitative assessment of EOPs in disinfections units and receiving water bodies

Waste water samples will be collected from inlet of disinfection unit and outlet of disinfection unit. Samples will also be collected from different points of disinfection tank. Moreover, samples will be collected from upstream and downstream of receiving water body to realize the impact of chlorinated water discharge on water quality with respect to EOPs concentration. The collected water samples will be characterized for various emerging oxidation precursors (EOPs): Trihalomethanes, THMs; Haloacetic acids, HAA; and N-Nitrosodimethylamine, NDMA)

5.3. Pilot- reactor study

Pilot scale reactor (1000 L) study will be conducted to remove the residual organics and nitrogen precursors and control the formation of EOPs in disinfection units. The low cost pollutants removal solutions of activated carbon, biochar and biological activated carbon (BAC) processes for removal of residual organics and nitrogen precursors will be studied.The effects of integration of a bio/activated carbon/ biochar filter on organic pollutants removal and EOPs formation in downstream disinfection process will be studied.

6. WORK PLAN (DURATION & ACTIVITY CHART)

S.No.	Work Element/ Milestone	1st Year				2nd Year				3rd Year			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Literature Review												
2	Hiring of project staff, equipment, purchasing/installation												
3	Performance evaluation of disinfection units in STPs												
4	Quantitative and qualitative assessment of EOPs formation in disinfection units												
5	Control of EOPs formation: Pilot reactor study												
6	Interim Report/Publications												
7	Final report submission												

7. Expected outcomes(Project deliverables): Specific outcome of the study are:

1. Comprehensive evaluation of disinfection units
2. Qualitative and quantitative database onEOPs formation in disinfection units
3. Technological solution to prevent the formation of EOPs through the integration of treatment units and design modifications
4. Technical report and papers

8. Practical relevance/utility of the project

This study could be proved as one of the most economical and environmental friendlies as it requires a lesser workforce and would be a potentially very essential data record that probes deeper to the chlorine disinfection in the working STPs. Regarding the cost efficacy and operational simplicity, this project is a potential capital and O&M cost savings as it will require quite less cost for analysis and recordkeeping. Analysis part can be done by lab-sitting, but regularity and consistency in work will be required.The outcome of this research will provide useful guidelines for safe chlorine disinfectiondose and control the formation of EOPs in the Ganga Basin.

9. Agencies, which can utilize the results of the project:

Effective disinfection Cl_2 dose a most challenging task for the municipal authorities not only at the local level but also at the global level, so the benefit is not limited to a group of people, but its advantage is widespread at National as well as International scale especially for the developing communities. The findings of the proposed study will be more relevant in the Indian context. The target beneficiaries of the proposed study will be:

- National River Conservation Directorate and Ministry of Environment, Forest & Climate Change can direct the application of technology on commercial scales once proved in field conditions. Ultimately, the **Central Pollution Control Board(CPCB)**can devise standards based on this technology for the control of EOPsformation and effective disinfectant dose.
- Different Consultants and Companies can get involved and improve the design conditions for an upscaled version, better treatment efficiencies, safe and sound operation, and proper maintenance.
- Municipal corporations will be the direct beneficiaries, as effective disinfection well managed. Moreover, the obligation of stringent rules for the disposal of treated of EOPs can be pacified as the treated wastewater can be further reused or mixed with stream.
- Researchers: The record maintenance of EOPs is highly required as limited data available on the EOPs characterization in different disinfection units of sewage treatment plants across India. The introduction of the findings of this study will benefit researchers working on municipal wastewater treatment as the option for efficient management of wastewater and disinfection technologies, and conservation of our water resources.

10. Participation and promotion among public and private sector and other government ventures:

It could be achieved by writing and publication of papers in international peer-reviewed journals (e.g., Water Research, Bioresource Technology, Hazardous Material, Waste Management and Environmental Science and Technology, etc.) by presenting lectures and posters at international conferences in the field of wastewater treatment, and environmental engineering. The NIH Roorkee has an extensive network of industry contacts, which will be used in the first instance to transfer the knowledge to the Indian and International companies active in relevant industrial sectors (water sector, chemical industry, environmental industry). In further support, a one-day workshop will be organized at NIH, Roorkee by the end of this project (depends on the funds' availability or extra funds provided from funding agency), broadly announced by NIH Roorkee thanks to their massive networking implication, to the industry active in water and wastewater management sector. The results of this project will have direct significance for the management and handling of EOPs in WWTPs of India.

11. Budget Details

Full Summary of Budget (In Rs)

S. No.	Head	Ist Year	IIndYear	IIIrd Year	Total
1	Manpower a. Senior Resource Person (50000/- + HRA) b. Junior Resource Person (35000/- + HRA)	660000 462000	660000 462000	660000 462000	1980000 1386000
2	Fabricated Systems/Models	-	500000	-	500000
3	Consumables (Glassware, Chemicals, Misc.)	600000	600000	400000	1600000
4	Travel (Sample collection,Meeting & Others)	500000	500000	200000	1200000
5.	Experimental charges	200000	200000	100000	500000
6	Miscellaneous expenditure	50000	100000	50000	200000
	Grand Total	**2472000**	**3022000**	**1872000**	**7366000**

Manpower Budget Details

Designation	**1st Year**	**2nd Year**	**3rd Year**	**Total (In Rs.)**
1. Senior Resource Person (50000/- + HRA monthly) 2. Junior Resource Person (35000/- + HRA monthly)	660000 462000	660000 462000	660000 462000	1980000 1386000
Total	**1122000**	**1122000**	**1122000**	**3366000**

Justification for Manpower

One Senior Resource Person with a Ph.D. degree and one Junior Resource Person with a post-graduation degree in Environmental sciences/ Chemistry/Environmental Engineering/Chemical Engineering with research experience in the field of water and wastewater treatment and water quality analysis will be required for the extensive fieldwork, analysis work, and piloting experiments.

Consumables Cost Details

Rs. In 1st Year	**Rs. In 2nd Year**	**Rs. In 3rdYear**	**Total (In Rs.)**
600000	600000	400000	1600000

Justifications for Consumables:

Chemical such as EOPs standards, solvents (methanol, acetone, heptane, acetonitrile, and dichloromethane), glass vials, microbiological media, chemicals, and glassware will be required for the analysis of samples and remediation of EOPs.

Travel cost details

Rs. In 1st Year	**Rs. In 2nd Year**	**Rs. In 3rdYear**	**Total (In Rs.)**
500000	500000	200000	1200000

Justifications for travel
Extensive field visit for sampling at STPs. Multiple times domestic travel (Field study, Meetings and National conferences)

Experimental Charges

Rs. In 1st Year	Rs. In 2nd Year	Rs. In 3rdYear	Total (In Rs.)
200000	200000	100000	500000

Justifications for Experimental Charges
Samples shall needs to be outsources for some EOPs analysis.

12. Contribution of PIs

PIs	Contribution
Dr. Vinay Kumar Tyagi, Sc. D, EHD	Performance evaluation of disinfection units, Quantitative and qualitative assessment of EOPs formation in disinfection units, Control of EOPs formation: Pilot reactor study; suggestive measure to reduce the DBPs formation in disinfection units
Dr. R.P Pandey Sc. G & Head, EHD	Wastewater quality Balancing Study
Dr. Mukesh K. Sharma, Sc F, EHD	DBPs analysis
Dr. Rajesh Singh Sc. D, EHD	Wastewater Quality: carbon and Nutrient removalstudy
Dr. Pradeep Kumar Sc. D, EHD	Hydrological Investigation and Characteristics (Impact on water resources up- and down-stream)
Dr. J.P.Patra, Sc D,	Tracer Study, CFD modeling in disinfection tanks
Dr. KalzangChhoden Sc. C, EHD	Wastewater Quality & Remediation Measures for DBPs formation
Dr. Bhanu P Vellanki, Professor, IITR	DBPs expert, analysis of DBPs, Pilot scale study
Dr. A. A. Kazmi, Professor, IITR	BiologicalWastewater treatment Expert &residual organic carbon & nutrients removal optimization in WWTPs

13. References

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GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Anupma Sharma	Scientist G & Head
2	Dr. Surjeet Singh	Scientist G
3	Sh. Nitesh Patidar	Scientist C
4	Mrs. Anjali Bhagwat	Scientist C
5	Mrs. Anju Choudhary	Scientist B
6	Dr.Satendra Kumar	Scientist B
7	Sh. Pintu Kumar Gupta	Scientist B
8	Sri Ram Chandra	SRA

APPROVED WORK PROGRAM FOR THE YEAR 2022-23

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Nitesh Patidar (PI), Gopal Krishan Anupma Sharma	2 years (08/20 – 07/22) *Status:* ***Completed***	Internal Study
2. NIH/GWH/NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar (PI), S. Singh, R. Singh, G. Krishan, S. S. Rawat, M.K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel	3 years (04/22 – 03/25) Status: **In-progress**	Internal Study
3. NIH/GWH/NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Surjeet Singh, Gopal Krishan, Sumant Kumar, Nidhi	2 years (04/22 – 03/24) Status: **In-progress**	Internal Study
4. NIH/GWH/NIH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	Nidhi Kalyani (PI), Anupma Sharma, Nitesh Patidar, Sumant Kumar	2 years (04/22 – 03/24) Status: **In-progress**	Internal Study
Sponsored Projects				
5. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency)	Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao *BGS, UK:* Dr. Dan Lapworth Dr. Alan MacDonald Dr. Daren Goody	5 years (12/17-11/22) *Status:* ***In progress (Extended)***	BGS, UK
6. NIH/GWH/PDS/17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar (Retd.), *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav *Sehgal Foundation:* Lalit Mohan Sharma	4 years (12/17-07/22) *Status:* ***Completed***	NHP under PDS
7. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-07/22) *Status:* ***Completed***	NHP under PDS
8. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) S. K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, S. Kumar, P.K. Mishra, V. Singh, N. Patidar, N. Kalyani *Partners* Haryana Irr. & WR Dept., UPGWD, UYRB, CWC	6 years (04/18-01/24) *Status:* ***In progress***	Special Project under "Centre of Excellence" (NHP)

9. NIH/GWH/DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (PI), Gopal Krishan, Nitesh Patidar, P.K. Mishra (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 01/24) *Status:* ***In progress***	DST
10. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator)	3 years (07/20 – 06/23) *Status:* ***In progress***	Federal Min. of Education and Research, Germany
11. NIH/GWH/DST-SERB/21-24	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), MS Rao	3 years (04/21 – 03/24) *Status:* ***In progress***	DST-SERB
12. NIH/GWH/APN/22	Capacity Development Program on Site Suitability Mapping for Managed Aquifer Recharge (MAR) under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools	Nitesh Patidar (PI), S. Singh, G. Krishan *IIT Roorkee (lead)*: Basant Yadav, Ashish Pandey, R D Singh, B. J. Deka *In-kind support:* KU, Japan: Yutaka Matsuno, PNU, South Korea: Sanghyun Jeong	10 months (01/22-10/22) *Status:* ***Completed***	Asia-Pacific Network (APN)

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-24

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar (PI), S. Singh, R. Singh, G. Krishan, S. S. Rawat, M.K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel	3 years (04/22 – 03/25) Status: **In-progress**	Internal Study
2. NIH/GWH/NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Surjeet Singh, Gopal Krishan, Sumant Kumar, Nidhi Kalyani	2 years (04/22 – 03/24) Status: **In-progress**	Internal Study
Sponsored Projects				
3. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) S. K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, S. Kumar, P.K. Mishra, V. Singh, N. Patidar, N. Kalyani *Partners* Haryana Irr. & WR Dept., UPGWD, UYRB, CWC	6 years (04/18-01/24) *Status: **In progress***	Special Project under "Centre of Excellence" (NHP)
4. NIH/GWH/DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (PI), Gopal Krishan, Nitesh Patidar, P.K. Mishra (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 01/24) *Status: **In progress***	DST
5. NIH/GWH/PDS/19-23	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI), Sudhir Kumar, J. V. Tyagi, (Superannuated), M. K. Sharma	3 Years 7 months 11/19 – 05/23 *Status: **In progress***	NHP under PDS
New Internal Studies				
6. NIH/GWH/23-24	Development of Archive of Soil Hydraulic Characteristics	Surjeet Singh (PI), Nitesh Patidar, M.K. Goel, Anupma Sharma, Anju Chaudhary	1 year (04/23 – 03/24) *Status: **New Study***	Internal Study
7. NIH/GWH/23-25	Enhancement and application of NIH_WISDOM	Nitesh Patidar (PI) Deepak Singh Bisht, M.K. Goel, T. Thomas, Sunil Gurrapu, Anupma Sharma, Surjeet Singh	2 years (10/23 – 09/25) *Status: **New Study***	Internal Study

1. PROJECT REFERENCE CODE: NIH/GWH/NIH/22-25

Title of the study: *Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin*

Study team ***:*** Sumant Kumar (PI), S. Singh, R. Singh, G. Krishan, S. S.Rawat, M.K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel

Collaborator : CGWB, Dehradun and NIT, Patna

Type of study **:** Internal

Date of start (DOS) **:** April, 2022

Scheduled date of completion: March, 2025 (3 Years)

Location **:** Ganga basin (From Gangotri to Patna)

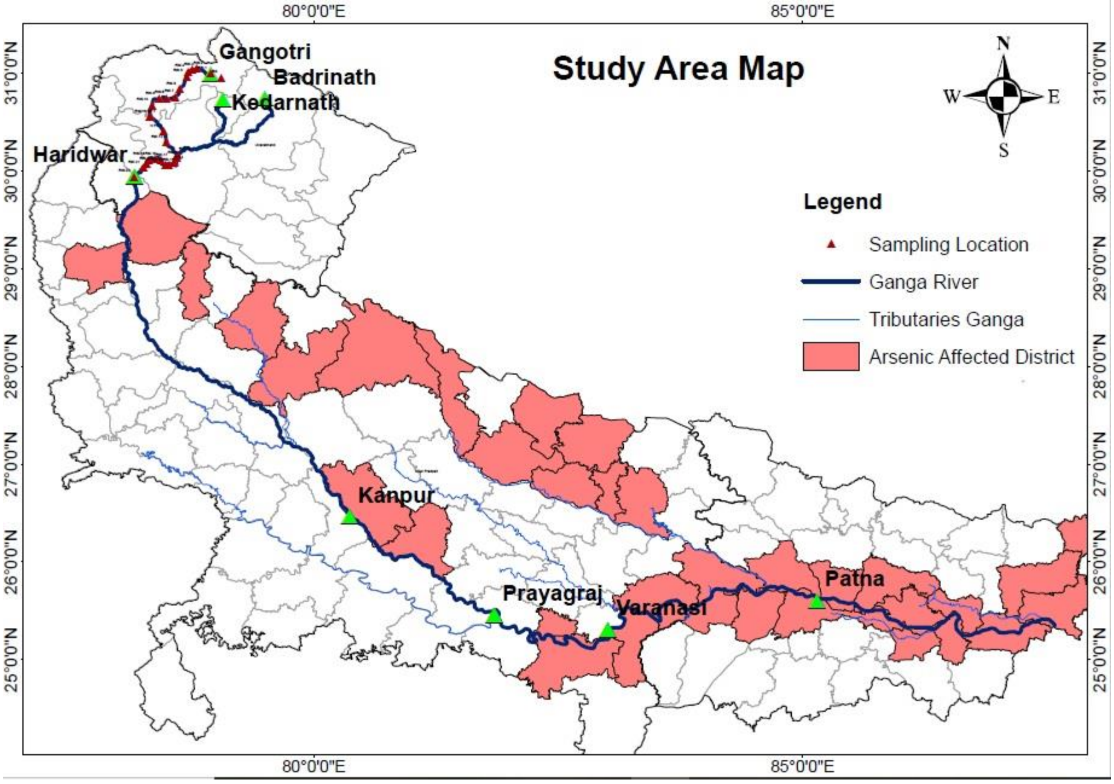


Figure – 2.1: Study Area Map

Objectives:

- Mineralogical characteristic of sediments and water chemistry in the Indian Himalayan region to detect genesis of arsenic.
- Demarcating safe aquifer for drinking water supply in arsenic affected areas.
- Performance evaluation of existing treatment units and their comparison in terms of cost, efficiency and ease of operation etc. in the central Ganga basin.
- Developing a new treatment technique with high removal efficiency in optimized cost.

Objectives vis-à-vis Achievements:

Objectives	Achievements
Mineralogical characteristic of sediments and water chemistry in the Indian Himalayan region to detect genesis of arsenic.	• Phase 1 Sampling of sediment and water completed from Gangotri to Haridwar. • Water quality (major Ions and trace metals) analysis have been completed. • Sediment Characterization: Grain Size analysis completed and XRD is in progress. • Further sampling from Haridwar onwards will be completed by March end.
Demarcating safe aquifer for drinking water supply in arsenic affected areas.	Geological Maps, Bore logs and water table maps are being obtained and prepared for further processing.
Performance evaluation of existing treatment units and their comparison in terms of cost, efficiency and ease of operation etc in the central Ganga basin.	• Questionnaire or Survey form is prepared and data will be collected from the field for further analysis and evaluation. • Data is being collected from the literature and reports available.
Developing a new treatment technique with high removal efficiency in optimized cost.	• After review and discussions it was agreed upon that that a biochar based adsorption system will be used. • Review and selection of raw material for biochar development is under process.

Statement of the problem:

Chronic exposure to groundwater having an arsenic concentration of more than 10 μg/L leads to numerous adverse health impacts like lower intelligence quotients, type 2 diabetes, skin lesions, melanosis, keratosis, and cancer etc. Arsenic (As) contamination of water is producing the greatest impact on livelihoods in terms of public health and thus arsenic calamity in the Ganga river basin put millions of population in danger. Arsenic is a natural constituent in bedrock and soil. It usually occurs at low concentrations (average 1–2 mg/kg) in the Earth's crust, but may be concentrated in certain rock types and especially in gold and sulphide-bearing ore deposits and occurrences. Pyrite [$FeS2$; or arsenopyrite $Fe(AsS)2$] and arsenopyrite [$FeAsS$] are typical sulphide minerals containing As. Weathering processes of rocks and minerals appears to be a major source of arsenic found in soils. Because it accumulates due to weathering and translocation in colloid fractions, the arsenic concentration is usually higher in soils than in parent rocks. The river Ganga and its major tributaries originate from the Himalaya and carry lots of sediment and these sediments determine the chemistry of water. In the mid Holocene period, the river Ganga is likely source to transport metals from Himalaya to the plains by erosion and sedimentation. The rivers originating from the Siwalik Hills are reported to release more arsenic and heavy metals from their sediments in comparison to those major rivers originating from the Higher Himalaya. In order to study the causes of arsenic occurrence in Ganga basin and its mobilization from solid to water phase, it is planned to carry out mineralogical, geochemical and mobilization study. The significance of the study is to help in demarcating safe aquifer, improved monitoring and mitigation measures at regional level.

With the grave problems of arsenic in India, Inter-Ministerial Group (IMG) on Arsenic Mitigation was constituted on the directions of Cabinet Secretariat by erstwhile Ministry of water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR) vide order No. 11014/1/2014-GW Desk (Part-V) dated 22 Dec. 2014 under the Chairmanship of Mission Director (MD), National Water Mission (NWM). The IMG desired that National Institute of Hydrology (NIH), Roorkee should take lead role on R & D activities related to "Arsenic Mitigation" as per the areas suggested by the 'Core Committee' on "Mitigation & Remedy of Arsenic Menace in India". The DoWR, RD & GR, Govt. of India (letter no. 50013/177/2020-E.II dated 20/07/2020) advised NIH to seek funding under the subcomponent “Sponsoring and Co-coordinating research in water sector” and accordingly may submit a project proposal to INCGW. A project proposal with budgetary requirement of 1259.50 Lakhs was submitted to INCGW with detailed work component and budget of multi-institutions. Now, INCGW provided their comments/suggestions for submitting the project proposal. The NIH is under process for incorporating the comments/suggestions and the project proposal would be submitted again to INCGW for their considerations. The GWHD proposed to start working on project components pertaining to NIH under internal funding till the funds are received from INCGW considering national importance of project.

Methodology:

The study will cover the detailed hydrogeology and geochemistry of the As-contaminated aquifer of the Ganga basin. A Pre-monsoon and post-monsoon grid-wise sampling would be done in upper and middle Ganga basin to study the spatio-temporal variation of water quality parameters including arsenic. The sediment samples at different location would be collected from upper and middle Ganga basin focusing on Himalayan sediments for sediment characterization using XRD & XRF techniques. The mineralogical study would help in identifying the minerals of arsenic present in the Ganga basin.

Integrated hydrological survey of arsenic concentrations would be carried out in the Ganga basin by using field test kits and collecting preserved samples for further analyses by more precise analytical instruments in laboratory. Groundwater and surface water samples will be collected during multiple field campaigns (pre-monsoon and post-monsoon season) from both deep and shallow aquifers. In addition to that, sediment samples (from hilly and plain region along with river bed material) would be brought out to lab for further analyses. The locations of the wells will be marked using a hand-held global positioning system (GPS). Unstable parameters and indicators of the oxidation state of ground water will be measured in the field. Field measurements will include temperature, electrical conductivity (EC), pH, oxidation-reduction potential (ORP) and dissolved O_2. The measured stable value of these water quality parameters will be representative of *in-situ* conditions. Samples will be filtered in the field with disposable 0.45-micron filters and will be collected for all major anions, cations and trace elements for further laboratory level analysis. Different analytical instruments would be used for analyses of ions and metals. Performance of existing treatment technology available and which are being used in arsenic affected areas would be evaluated. The influent and effluent of treatment unit would be tested and then removal efficiencies may be ascertained. It is also planned to develop cost effective treatment units in Lab and it may be upscaled at later stage.

Analysis of Results:

In the first phase of sampling the water (surface and groundwater) and sediment samples were collected from Gangotri to Haridwar on the stretch of Ganga River. A total 25 water samples and 32 sediment samples were collected. In situ parameters like pH, EC, ORP and DO were measured on the sampling sites. The pH of the water samples of study area varies from 7.1 to 7.5 (mean 7.3) for groundwater, and 6.8 to 8.5 (mean: 7.9) for Ganga river. It is observed that the pH values are increasing as the sampling location descends from the origin towards Haridwar. The EC of the water samples varies from 206 to 393 µs/cm (mean 301 µs/cm) for groundwater, and 107 to 246 µs/cm (mean: 161 µs/cm) for Ganga river. It has been observed that the EC values are following a declining trend in the Bhagirathi river from Gangotri to Devprayag, thereafter the EC values follow an increasing trend up to Haridwar. The DO values in the river vary between 7.3 to 8.5 mg/L with an average value of 8.02 mg/L and in groundwater it varies from 2.4 to 3.5 mg/L (mean: 2.8.). The ORP of the water samples in the study area varies between 84 to 183 mv (mean 138 mv) for river water, and 27 to 125 mv (mean: 67 mv) for groundwater. The ORP values are observed to be increasing from Gangotri to Haridwar which can be due to the increase in the surface water temperature.

The water samples were analyzed for trace metals (As, Fe, Mn, Zn, Cu, Cr, Cd, Ni, Pb) using inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES, Agilant 5110 VDV). In majority of the water samples, the trace metal concentration were below the permissible level except in few instances. The concentration of Al, Fe and Mn were found to be higher than permissible limit in bulk of the samples. The As concentration in the water samples in the study area varies between ND to 14.07 µg/L with and average value of 5.9 µg/L. Out of the 22 river water samples, nine samples were having *As* concentration more than the permissible limit but were below the acceptable limit of drinking water standards. None of the groundwater samples were found to be contaminated with *As*. In groundwater samples, *Fe* concentrations were observed to be very high that might be due to the corrosion of iron pipes in the hand pumps. Further, sediment characterization and the remaining analysis of water samples are under process.

Data Requirements:

- Geological map and bore logs of various location
- Groundwater levels
- Surface water and groundwater quality etc.

Laboratory Facility used during the Study:

- Soil Water Laboratory
- Nuclear Hydrology Laboratory
- Water Quality Laboratory

Study Benefits /Impact:

A project report will be prepared highlighting the genesis of arsenic and its mobilization from solid to liquid phase. The research output and development of new technique for arsenic removal may help stakeholders for deciding the water supply management strategies in arsenic affected areas. The findings of the study will be presented in conferences/workshops and published in journals. Stakeholder (Public Health Engineering Department, Jal Nigam, Water Resources Department, Department of Drinking Water and Sanitation, Ministry of Jal Shakti etc.) engagement would be done for improving their knowledge and application of various mitigation options.

2. PROJECT REFERENCE CODE: NIH/GWH/NIH/22-24

Title of the Project: *Conjunctive Management of Water Resources in IGNP Command*

Study team:	PI	Dr. Nitesh Patidar, Scientist-C
	Co-PIs	Dr. M.K. Goel, Scientist-G
		Dr. Anupma Sharma, Scientist-G
		Dr. Surjeet Singh, Scientist-F
		Ms. Nidhi Kalyani, Scientist-B

Type of study: Internal (On-going study)

Duration: Two years (April 2022 – March 2024)

Objectives

1. Analysis of present groundwater scenario in enroute command of IGNP
2. Mapping of water-logged area in IGNP command using GW observations
3. Estimation of GW recharge from rainfall, canal and irrigation under present and future climatic scenarios
4. Conjunctive management of water resources in enroute command area of IGNP canal

S. No.	Study objectives	Achievements
1	Analysis of present groundwater scenario in enroute command of IGNP	*Under Progress* The data of groundwater levels acquired from CGWB are analyzed. Trend analysis was performed.
2	Mapping of water-logged area in IGNP command using GW observations	*Under progress* The water-logged areas are being identified using remote sensing and groundwater data.
3	Estimation of GW recharge from rainfall, canal and irrigation under present and future climatic scenarios	*To be started* The data collection for modelling is in progress.
4	Conjunctive management of water resources in enroute command area of IGNP canal	*To be started*

Background

Conjunctive management of surface water and groundwater for irrigation is recognized as an effective solution to water logging and root zone salinity. The conjunctive utilization of water resources also ensures consistent water availability for irrigation and support sustainable water management. However, despite these advantages the conjunctive management of water resources is scant in canal commands. The Indira Gandhi Nahar Pariyojana (IGNP) provides irrigation to an area of 1.963 million hectare (CCA) in Rajasthan. The project also provides domestic water supply to most of thar dessert of Rajasthan and is therefore the most important water source in the arid Rajasthan. Since the inception of the project, there has been various issues related to rising water table and increasing soil salinity. Several studies were conducted to assess the impact of canal on groundwater levels and water logging. It was observed that before the canal construction (before 1952) the depth to groundwater used to vary between 40 and 50 m. After the inception of irrigation through stage-I of IGNP groundwater level started rising. In 1972-82 the rise in groundwater level was observed to be 1.17 m/year. Later in 1995, an area of around 10% of CCA of stage-I was waterlogged and around 25% area was under critical condition (depth to GW in range 1-6 m). Such rise in groundwater level transports the salts from deeper soil layers to surface and impact the agricultural productivity in the area.

The present scenario of groundwater and mapping of water-logged area is essential in the IGNP command for effective management of land and water resources. Such analysis would help in quantifying the current potential of groundwater in conjunction with canal water to maximize the irrigation potential in command and to contain salt mobilization in root zone.

Study area

The IGNP project was initiated in the late 50's and is situated in the districts of Sriganganagar, Hanumangarh, Bikaner, Churu, Jaiselmer, Barmer, and Jodhpur. It has a CCA of 1.963 million hectares. The project was completed in two stage, Stage-I having a 204 km long feeder which originates from Harike Barrage, Punjab, to reach Masitawali, Rajsthan, and a 189 km long main canal from Masitawali to Chattergarh in Bikaner district. Stage-II is having a 256 km long main canal from Chattergarh to Mohangarh in Jaiselmer.

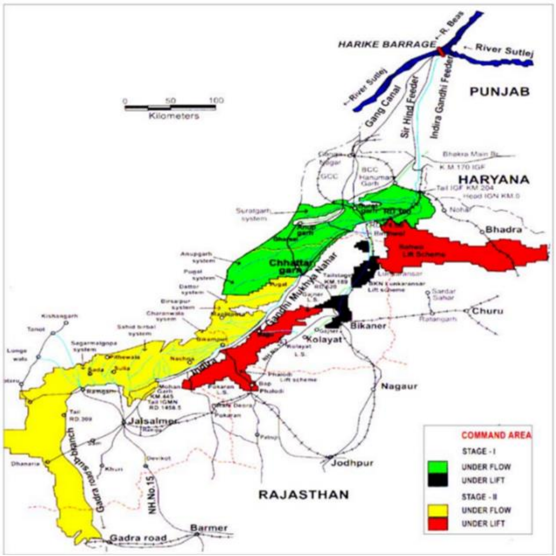


Image source: Gupta et al. (2002)

Figure - 3.1: Indira Gandhi Nahar Pariyojna (IGNP) command under stage-I and stage-II

Methodology

The assessment of the present groundwater scenario will be done utilizing the groundwater observation of Central Ground Water Board (CGWB). Trend analysis will be performed on groundwater levels to identify the trend in groundwater. The mapping of water-logged area will be performed using the groundwater data. The conjunctive management of surface water and groundwater requires an integrated simulation-optimization model. A model developed at NIH which integrated Google Earth Engine (GEE), an surface water module and MODFLOW, will be utilized for estimating recharge to groundwater. A system model was developed at NIH which will be used to simulate the demand-supply and recharge due to canal percolation and irrigation. Iterative simulation runs will be performed to optimize the groundwater extraction so as to contain the rising water level and increase irrigation intensity. The Effect of climate variability will be considered using the most recent data of climate projections.

Progress

The groundwater level data obtained from CGWB are processed for the assessment of present groundwater status in the IGNP. A python program is developed to pre-process the data, generate groundwater level maps and apply modified Mann-Kendall test. Trend analysis was performed on the groundwater data from 2001 to 2018. It is found that approximately 60% of the wells having significant rising trend in groundwater, while 16% of the wells indicate falling trend. To investigate the area under water-logged in the command, global surface water data is used which shows percentage of occurrence of water during the past ~35 years. The preliminary analysis shows two hotspots of water logging in the area, one near Suratgarh and one in the North of Jaisalmer. Further investigations to quantify the waterlogged area using time series analysis of Landsat images is in progress. The database development is in progress.

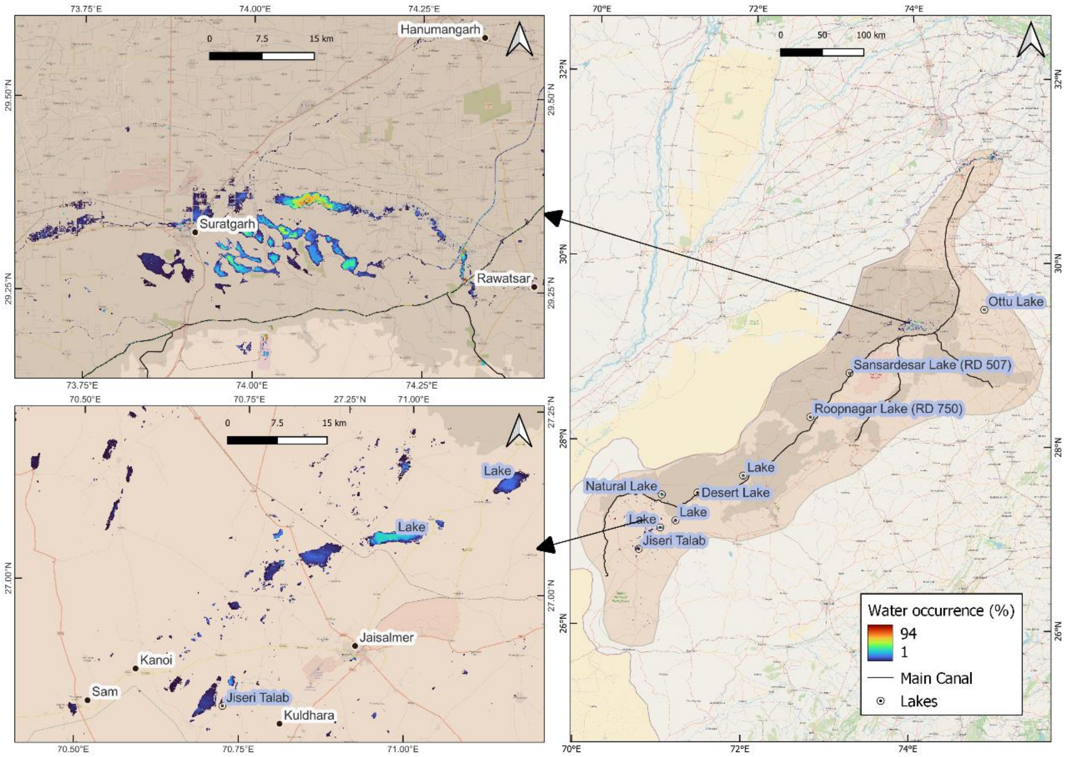


Figure - 3.2: A few patches of water-logged area identified using remote sensing data

3. PROJECT REFERENCE CODE: NIH/GWH/PDS/18-22

Title of the study: *Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi*

Study Team: Dr. Anupma Sharma, Sc. G (PI); Dr. S. K. Jain, Sc. G; Dr. Archana Sarkar, Sc. F; Dr. M. K. Sharma, Sc. F; Dr. L. N. Thakural, Sc. D; Dr. S. Kumar, Sc. D; Dr. P.K. Mishra, Sc. D; Dr. Vishal Singh, Sc. D; Dr. Nitesh Patidar, Sc. C; Ms. Nidhi Kalyani, Sc. B

Type of study: Special Study under Centre of Excellence in Hydrological Modelling (NHP)

Date of start: April 2018

Duration of study: Six years

Location Map:

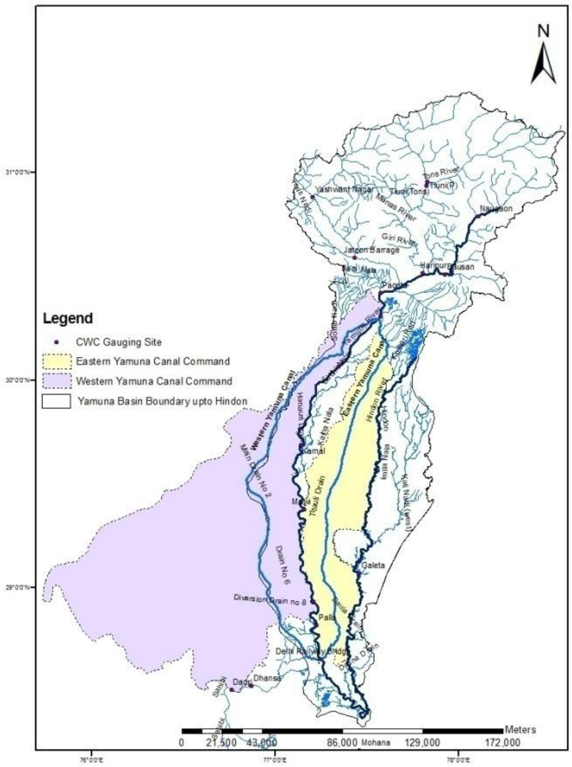


Figure - 8.1: Study area showing the Upper Yamuna Basin and command of EYC and WYC

Study objectives:

1. Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality
2. Quantification of the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling for the Tons river
3. Assessment of changes in baseflow contribution to river Yamuna.
4. Assessment of present and future water availability under alternate scenarios of climate change
5. Integrated water allocation planning based on present and future scenario of water availability for (i) Eastern Yamuna Canal Command, (ii) Western Yamuna Canal Command
6. Formulation of adaptation measures in the context of climate change
7. Flood frequency analysis and flood plain mapping of river Yamuna
8. Assessment of anthropogenic activities on water quality

9. Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable groundwater resources
10. Roll out of technical know-how through training workshops for partner organizations

Objectives vis-à-vis Achievements:

Objectives	**Achievements/ Activities**
Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality	Application of hydrological models completed for SWAT, HEC-RAS, VIC, QUAL2K. Application ongoing for MODFLOW. Includes data collection from various agencies, field visits, data processing and analysis. In addition, equipment purchased under project.
Quantification of the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling for the Tons river	Data processing and work on snowmelt runoff model SWAT for Himalayan portion (incl. Tons).
Assessment of changes in baseflow contribution to river Yamuna	Assessment of changes in baseflow contribution to river Yamuna completed.
Assessment of present and future water availability under alternate scenarios of climate change	Extracted data for study area, data processing, prepared maps for climate change indicators
Integrated water allocation planning based on present and future scenario of water availability for (i) Eastern Yamuna Canal Command, (ii) Western Yamuna Canal Command	In progress using MODFLOW for Yamuna-Hindon Interbasin. Groundwater related data collected for Eastern Yamuna Canal Command. Completed application of WA+ tool using satellite measurements for the study area.
Formulation of adaptation measures in the context of climate change	To be taken up.
Flood frequency analysis and flood plain mapping of river Yamuna	River cross-section survey completed. Flood frequency analyses completed. Flood plain mapping for selected reach.
Assessment of anthropogenic activities on water quality	Field visits undertaken and data collected from central/ state agencies. Assessment of surface water quality of Yamuna river completed. Groundwater samples collected from different locations and analyzed.
Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable gw resources	Modeling using GIS based WetSpass distributed model. Field and lab experiments for soil parameters for selected sites completed.
Roll out of technical know-how through training workshops for partner organizations	One online training course organized for 24 officers of UP Ground Water Department.

Deliverables:

1. Application of various models pertaining to surface water hydrology, groundwater hydrology, basin planning and their inter-comparison in respect of UYB;
2. Evaluation of the impact of climate change, land use change and population growth on the water resources in UYB;
3. Evaluation of impact of climate variability on renewable groundwater resources;
4. Training Workshops for State Department officials of UP and Haryana.

4. PROJECT REFERENCE CODE: NIH/GWH/DST/19-23

Title of the study : *Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water*

Study Team: Dr. Anupma Sharma, Sc. G (PI); Dr. Nitesh Patidar, Sc. C; Dr. P.K. Mishra, Sc. D, Dr. Gopal Krishan, Sc. D

Type of study (sponsored/consultancy/referred/internal): Sponsored by DST

Nature of study: Applied research

Duration: 02/2019 to 01/2024

Lead agency and project partners:
CAZRI Jodhpur (Lead agency),
NIH Roorkee,
IISWC Dehradun,
CSWRI Bikaner,
CIAH Bikaner,
NIAM Jaipur

Aims
- Enhancing water productivity at farming system as well as its components level
- Analyzing future demand and supply of water at regional and sub-regional level
- To develop improved methods for reusing industrial effluents in agriculture
- Capacity building of stakeholders in enhancing water productivity and developing policy guidelines

Objectives
I. To enhance water productivity in farming systems/regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)
II. To develop improved methods for reusing industrial effluents in agriculture
III. To analyze future demand and supply of water at regional and sub-regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)
IV. To develop policy guidelines and capacity building of stakeholders

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Enhancing water productivity at farming system as well as its components level	Field experiments undertaken with CAZRI to study the impacts of different irrigation schedules on the water balance components. Numerical modeling to study various irrigation management scenarios. Database buildup for WA+ tool to process spatial information on water depletion and net withdrawal using satellite measurements in respect of study area. Equipment purchase completed.
Analyzing future demand and supply of water at regional and sub-regional level	To be taken up with project partners
To develop improved methods for reusing industrial effluents in agriculture	Work by project partners
Capacity building of stakeholders in	To be taken up with project partners

enhancing water productivity and developing policy guidelines	

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Soil and Water Laboratory
- Water Quality Laboratory

Deliverables & Beneficiaries: Beneficiaries will include farming communities in arid regions of Rajasthan. Deliverables include research papers, reports, software, manuals, brochures, flyers, users' interaction workshops.

5. PROJECT REFERENCE CODE: NIH/GWH/PDS/19-23

Title of the Study: *Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures*

Study Group:

Project Investigator/Co-Project Investigator
Er. Anjali, Scientist C, GWHD
Dr. Sudhir Kumar, Scientist G & Director NIH
Dr. J. V. Tyagi, Scientist G (Superannuated)
Dr. M. K. Sharma, Scientist F, EHD

Scientific/Technical / Project Staff
Mrs. Babita Sharma, RA, EHD
Ms. Beena Prasad, RA, EHD
Mr. Chandra Prakash, PA, GWHD
Ms. Shally Shaini, PA, GWHD

Collaborating Agency
Dr. G.Vijay Kumar, Senior Hydrologist, CGWB (Delhi Unit)

Type of Study: Sponsored project by NHP (PDS), Budget: Rs 76,10,000/-

Nature of Study: Applied Research

Date of start: 1 November, 2019

Scheduled date of completion: 31 May, 2023

Duration of the Study: 3 Years (+7month extension)

Study Objectives:

i) Understanding of hydrodynamics of groundwater flow in the study area.
ii) Chemical characterization of Leachate.
iii) Isotopic characterization of leachate and its variation due to recharge and extraction of groundwater.
iv) Assessment of Micro-plastic and metals (Hg, Ni, Co) in landfill leachate.
v) Modelling of leachate migration pattern in groundwater in space and time.
vi) Suggesting ameliorative measures for contaminant plume migration.
vii) Dissemination of knowledge and findings to stakeholders through manuals, leaflets, booklets and workshops/training programs.

Statement of the Problem:

The growth in population, urbanization and industrialization has led to the increase in the generation of solid waste all over the world. It is believed that the rate of waste generation is an index of socio-economic development and an economic prosperity of a country. This is evident from the fact that the rate of waste generation is more prominent in the developing countries where there is an increased rate of unplanned urbanization of the cities.

In India, the total Indian urban population amounts to approximately 377 million (Census of India 2011). The cities which have more than 100,000 populations contribute to more than 72 percent of the total municipal solid waste. The growth rate of population in urban India is much higher than that in rural India. The Census figures also show Delhi to be the most urbanised State in India. Since waste generated by the city depends on its population and per capita income, it is estimated that the quantity of Municipal Solid Waste (MSW) would reach 17,000 – 25,000 MT/day by 2021 (Talyan et al.,2007).

For solid waste management in Delhi, twenty landfill sites were identified and developed since 1975, and of which 15 have already been closed and two were suspended. At present only three landfill sites are in operation. They are namely, Bhalaswa catering the needs of northern part of Delhi, Okhala in the southern part and Gazipur in the eastern part of Delhi.

The dumping of waste in these non-engineered landfill sites contributes to percolation of leachate in the groundwater. These percolating liquids have high concentration of hazardous chemicals. The harmful constituents of leachate then move along the groundwater in the surrounding region rendering it unfit for human consumption and pose various health risk.

The various attempts made so far to model leachate movement suffer from a common problem that no surety can be established as to whether the pollution is result of leachate or any other source is contributing towards groundwater deterioration in that region. The current study focuses on modeling of leachate movement through groundwater and apportionment of leachate which has not been attempted so far.

Approved Action Plan/Methodology:

i) Literature review on chemical and isotopic characterization of leachate, groundwater contaminant transport modeling etc.
ii) Field survey of the region and groundwater sampling – using standard protocols.
iii) Characterization of leachate using EPA methods- TCLP (method no.- 1310) & column study (method no.- 1312).
iv) Collection of groundwater levels to ascertain the flow direction.
v) Identification of groundwater recharge and discharge areas.
vi) Collection of groundwater samples on bi-monthly basis at identified locations.
vii) Analyzing the physico-chemical parameters: pH, EC, DO, COD, TOC, Major anions, cations, and trace metals (Fe, Mn, Zn, Pb, Cd, Cr, Radium etc).
viii) Analysing the stable isotopic characteristics of leachate and groundwater at various identified locations.
ix) Analysing the groundwater samples and leachate for micro-plastic.
x) Processing of hydro-chemical and isotopic data on bi-monthly basis.
xi) Modeling the leachate migration from the landfill to groundwater table. The model will be developed for one dimensional vertical transport of contaminants through unsaturated zone.
xii) Modeling of leachate plume movement in groundwater will be performed using MT3D MODFLOW and HELP. The leachate transport model will be calibrated based on chemical and isotopic data.
xiii) Suggesting ameliorative measure for containment of contaminant plume based on groundwater modeling.

Timeline:

S. No.	**Activities**	**YEAR 1**				**YEAR 2**				**YEAR 3**			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q4
1.	Hiring of manpower & training												
2.	Purchase of equipment & consumables												
3.	Upgrading literature and data collection												
4.	Delineation of villages and finalization of sampling												

	location												
5.	Collection and analysis of samples												
6.	Statistical analysis of data and Carcinogenicity test												
7.	Contaminant remediation												
8.	Training & capacity building												
9.	Scientific publications												
10.	Final technical report												

Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1st Year	Literature survey	Field investigation, data collection and literature survey	Groundwater sampling and data processing	Groundwater sampling and analysis, estimation of flow parameters, and interim report
2nd Year	Groundwater sampling and analysis, and leachate characterization	Groundwater sampling and analysis, plume characterization and model conceptualization	Groundwater sampling and analysis, model conceptualization, training and workshop	Groundwater sampling and analysis, development of mathematical model, and interim report
3rdYear	Development of mathematical model	Computational runs with the developed model and identification of vulnerable areas and hot spots	Computational runs with the developed model and identification of vulnerable areas and hot spots	Finding ameliorative measures, training, workshop and report writing

Objectives and achievement during last six months:

S. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• Groundwater sample collection from 130 grids from the vicinity of landfill. • Leachate Samples taken from the landfill.
2.	Decolourization of samples	• Samples colour removal was undertaken • Reasons for coloured samples was identified. • Field applicability of chemical treatment assessed.
3.	Literature survey	• Literature on Microplastics, leachate characterization and isotopes in landfill was extensively surveyed.

Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
The study was appreciated by the PDS committee	

Analysis & Results:

- Field Survey was undertaken for selecting sites for Leachate sampling.
- For understanding the basic characteristics of leachate, preliminary samples were collected in order to find out the suitability of various experiments and to identify the procedures need to be followed in future.
- The physico-chemical, metal contents and isotopic parameters of Leachate was identified.
- The physico-chemical, metal contents and isotopic parameters of Groundwater in the study arae identified.
- Presence of microplastics in leachate samples detected.
- Modelling movement of contaminant within the landfill.
- Source Identification with statistical analysis.
- Training of Groundwater Monitoring and Modelling.

End Users / Beneficiaries of the Study: Policy makers and planners of State Government Organizations, Delhi municipal corporation and CGWB and state groundwater board.

Deliverables: Technical report and research papers, First-hand information on water quality in and around Gazipur Landfill site, groundwater model simulating plume movement and fate and origin of pollutants will be described.

Major items of equipment procured: Procurement procedure for FTIR imaging system to be purchased
MODFLOW purchased and TLC Meter purchased.

Lab facilities used during the study: Water Quality Laboratory (NIH) / Isotope Lab (NIH)

Data procured or generated during the study: Water quality data of the area

Study Benefits / Impacts:

The study will identify the chemical and isotopic characteristics of leachate originating from the landfill site and help explaining its role in groundwater pollution. A new dimension will be added to leachate transport through groundwater. Findings of the proposed PDS will be published in the form of leaflets/reports/research papers. It will also provide new data sets on leachate and groundwater quality, and thematic maps of contaminant plumes, vulnerable areas and hot spots of groundwater contamination in the study area.

Involvement of end users/beneficiaries: CGWB

Specific linkage with Institution and /or end users / beneficiaries: East Delhi Municipal corporation, CGWB.

Shortcoming/Difficulties: NONE

Future Plan:

- Field Visits will be planned and sample collection will be undertaken.
- Groundwater Modelling and Contaminant Transport
- Modelling microplastic movement in soil and Groundwater
- Source Apportionment

6. PROJECT REFERENCE CODE: NIH/GWH/NIH/23-24

Title of the Project: *Development of Archive of Soil Hydraulic Characteristics*

Study team:	PI	Dr. Surjeet Singh, Scientist-G
	Co-PIs	Dr. Nitesh Patidar, Scientist-C
		Dr. M.K. Goel, Scientist-G
		Dr. Anupma Sharma, Scientist-G
		Ms. Anju Chaudhary, Scientist-B

Type of study: Internal (***New Study***)
Duration: One year (April 2023 – March 2024)

Background

Soil Hydraulic Properties, such as soil texture, hydraulic conductivity and soil moisture retention curve etc. are important inputs to various hydrologic analysis and modelling. Soil Water Laboratory of NIH has been conducting such investigations in various parts of India under various R&D studies funded by NIH and external agencies. Scientist of NIH and staff of Soil Water Lab make considerable efforts to collect soil samples from the field and conduct various investigations in the lab to derive soil hydraulic properties. A total of ~3,330 soil samples have been tested since 2011 which provide abundant data for various hydrologic analysis. The analysis includes soil texture identification with measurement of sand, clay and silt fractions, analysis on pressure plate apparatus to derive soil moisture at different suction pressures for soil moisture characteristic curve, analysis of soil organic contents, estimation of soil hydraulic conductivity, etc. Such data are although very useful for hydrologic modelling, these are rarely available.

It is envisaged that such soil test results conducted in past historical period (with a buffer gap of 4 years for reporting/publication by the project team), if published through a GIS-portal on NIH website, could help researchers and planners in their analysis towards better water management. In this context, it is planned to develop an Archive of Soil Hydraulic Characteristics to store the soil-test results in digital format and disseminate them through a GIS portal.

Objectives

The prime objective of the study is to develop a web-based system to store and disseminate soil hydraulic characteristics analyzed in Soil Water Lab of NIH. The specific objectives of the study are as follows:

I. Development of archive of soil hydraulic characteristics. The results of soil analyses performed during the past years (2011-2022) will be digitized in a standardized format to append in the archive.
II. Development of a web-based GIS-dashboard to publish the soil hydraulic characteristics.
III. Development of an automated system to store the results of soil hydraulic analysis to be performed in future in the archive and publish them on the portal.

Methodology

Digitization

The soil test results in Soil Water Lab used to be stored in the form of printed/hand written sheets. These data are to be converted to digital format in order to process, store in the archive and publish on the portal. A format for each soil hydraulic characteristic will be decided and the same will be followed while converting the data from hard copies to digital sheets.

Development of archive
To store results of all the analysis performed in the past and to be performed in the future, a archive will be developed. The archive will store all data in the desired format for further processing for GIS analysis.

Development of GIS-dashboard
To publish the data stored in the archive, a GIS-dashboard will be developed. Python programming with HTML and CSS will be used to develop the web-based GIS-dashboard. The dashboard will fetch the data from the archive and will display it on the dashboard in the form of interactive maps, plots and tables.

Development of automated system
An automated system is to be developed for processing and storing the results of soil analysis to be performed in the future. This will enable automated data insertion to the archive and allow automated publishing after the analysis completes the assigned lock-in period (say four years). This system will be developed in Python which will communicate with the soil archive and the dashboard.

7. PROJECT REFERENCE CODE: NIH/GWH/NIH/23-25

Title of the Project: Enhancement and *application of NIH_WISDOM*

Study team:	PI	Dr. Nitesh Patidar, Scientist-C
	Co-PIs	
		Dr. Deepak Singh Bisht, Scientist-C
		Dr. M.K. Goel, Scientist-G
		Dr. T. Thomas, Scientist-F
		Dr. Sunil Gurrapu, Scientist-D
		Dr. Anupma Sharma, Scientist-G
		Dr. Surjeet Singh, Scientist-F

Type of study: Internal (***New Study***)

Duration: two years (Oct 2023 – Sep 2025)

Background

The excessive groundwater withdrawal led by growing water demands has resulted in rapid and widespread groundwater declines in many parts of India. To manage water resources in a sustainable manner, comprehensive understanding of groundwater system is essential. Of particular importance are the understanding of recharge processes, quantification of recharge from various sources, such as rainfall and surface water bodies, assessment of the impacts of groundwater withdrawal, and understanding the exchange of fluxes between surface and subsurface hydrological systems.

Web-based Integrated catchment modelling System for Decision Making (WISDOM) is developed recently at NIH. For integrated hydrologic modelling a model, named “GEE-MODFLOW” is developed as a part of WISDOM for groundwater recharge estimation. Estimation of recharge requires simulation of both the surface and subsurface hydrological processes. The water that reaches to groundwater table, so called recharge, is an end result of various processes happening at surface/subsurface which are driven by various influxes, such as infiltration and irrigation, and outfluxes, such as root water uptake and soil evaporation. Therefore, in order to mimic all such processes, an integrated model is needed. The integrated GEE-MODFLOW model consists of various modules which simulate surface and sub-surface processes in unsaturated and saturated zones. The model has three simulation modules, namely Root Zone Flow (RZF), Unsaturated Zone Flow (UZF), and Groundwater Flow (GWF). During the development, the GEE-MODFLOW was tested in the Hindon river basin for groundwater recharge estimation. However, to ensure its applicability in other areas, a detailed testing and validation is required. Therefore, it is planned to test the GEE-MODFLOW model in other basins.

The current version of WISDOM has mainly two models, the RZF (developed at NIH) and MODFLOW (developed by USGS) which was developed to estimate groundwater recharge, although it estimates all other hydrological components, such as runoff, ET, soil moisture and streamflow. WISDOM have several advantages, such as easy-to-use and free access through web-browser. To extent its capability to model surface hydrology using state-of-the-art models, such Variable Infiltration Capacity (VIC) model, integration of a surface hydrologic model with MODFLOW is proposed. Further, inclusion of tools, like map creator, trend analysis, etc., would further enhance the utility of NIH_WISDOM.

Objectives

The main objective of the study is to enhance and test the NIH_WISDOM for integrated modelling. The specific objectives of the study are as follows:

I. Integration of surface hydrologic model in NIH_WISDOM

II. Development of tools for hydrologic analysis such as, map creator, trend analysis, etc.
III. Testing of developed models by comparing simulated groundwater recharge with CGWB's assessments in an alluvium aquifer.
IV. Application of NIH_WISDOM in a hard-rock area by developing equivalent porous media model.

Study area
Two basins/inter-basins will be identified for testing the GEE-MODFLOW model. An alluvium aquifer will be identified based on data availability, possibly in the Gangatic plain. Similarly, one basin/sub-basin will be identified in a hard-rock region where both the groundwater and streamflow data are available to test the model.

Methodology
The VIC model will be integrated with the MODFLOW model for integrated modelling. An interface for the integrated VIC-MODFLOW model will be developed and included in the NIH_WISDOM. The tools, such as map creator and trend analysis, will also be integrated in WISDOM using Python programs.

The NIH_WISDOM will be applied to an alluvium and a hard-rock area for estimating various hydrologic components, such as recharge, runoff, ET, streamflow, etc. In the hard-rock area, an equivalent porous media model will be developed by calibrating the GEE-MODFLOW/VIC-MODFLOW with the observed groundwater head. The simulated groundwater head, groundwater recharge and streamflow will be compared with observed data as procured by CGWB and CWC.

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. S D Khobragade	Scientist G & Head
2	Dr. M S Rao	Scientist F
3	Dr. Soban S. Rawat	Scientist F
4	Dr. Santosh M. Pingale	Scientist D
5	Dr. Gopal Krishan	Scientist D
6	Sri Rajeev Gupta	Scientist B
7	Sri. Ruchir Patidar	Scientist B
8	Sri V K Agarwal	PRA
9	Sh. Drona Khurana	PRA
10	Sri Vishal Gupta	SRA
11	Sri Rajkumar Dewansi	RA

APPROVED WORK PROGRAMME FOR 2022-23

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Assessment of dissolved radon concentration in groundwater of Uttarakhand	**Hukam Singh (PI),** M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal	1 ¾ years (04/21-12/22)	Completed Study
2..	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	**SD Khobragade (PI),** Dr. Vishal Singh, Sudhir Kumar	3 years (04/22-03/25)	On-Going Study
3.	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	**Soban Singh Rawat, (PI)** Sudhir Kumar, Santosh M. Pingale, P K Mishra, D. S. Bisht, Rajesh Singh	3 years (04/22-03/25)	On-Going Study
4	Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies	**S.M. Pingale** (PI) SS Rawat Rajeev Gupta	2 years (04/23-03/25)	On-Going Study
SPONSORED PROJECTS:				
1.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	**M. Someshwar Rao (PI)** Sudhir Kumar	3 Years (06/16 - 12/22)	Continuing Study IAEA under CRP
2.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	**Sudhir Kumar (PI)** M. Someshwar Rao Vipin Aggarwal	3 ½ year (01/18 – 06/22)	Continuing Study NHP (PDS)
3.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	**M. S. Rao (PI),** Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan	3 ½year)01/ 18–06/22(	Continuing Study NHP (PDS)
4.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	**Suhas Khobragade** (PI) Sudhir Kumar	3 Years)01/ 18–062/2(	Continuing Study NHP (PDS)
5.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	**Sudhir Kumar (PI)** SM Pingale	2 years (06/19 – 09/22)	Continuing Study (IIT Bombay, Mumbai)
6.	Web-GIS Based Spring Inventory for Vulnerability Assessment and	**S S Rawat (PI)** Sudhir Kumar	4 Years 17/08)–	Continuing Study NHP (PDS)

S. N.	Project Title	Study Team	Duration	Status
	Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh	P G Jose, Suman Gurjar, D S Bisht	0922/)	
7.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	**S S Rawat (PI)** P G Jose, Suman Gurjar, D S Bisht	3 Years)01/ 19– 09/22(	Continuing Study (NMHS)
8.	Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures	**Anjali (PI)** Sudhir Kumar, J. V. Tyagi M. K. Sharma Partner: CGWB (Delhi unit)	3½ years (11/19 – 06/23)	Continuing Study NHP (PDS) Transferred from EHD
9.	Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river	**Sudhir Kumar,** (Proj. Coordinator), M. K. Sharma, (PI), Suhas Khobragade, Anjali, Vishal Singh, SM Pingale, Nitesh Patidar, Surjeet Singh.	5 Years)04/22 – 03/27(	DST

RECOMMENDED WORK PROGRAMME FOR 2023-24

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	**SD Khobragade (PI),** Dr. Vishal Singh, Sudhir Kumar	3 years (04/22-03/25)	On-Going Study
2..	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	**Soban Singh Rawat, (PI)** Sudhir Kumar, Santosh M. Pingale, P K Mishra, D. S. Bisht, Rajesh Singh	3 years (04/22-03/25)	On-Going Study
3.	Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India	**Gopal Krishan (PI)** M.S. Rao *SKUAST-Srinagar* Rohitashv Kumar	1.5 years (09/22 – 03/24)	On-Going Study
4	Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies	**S.M. Pingale** (PI) SS Rawat Rajeev Gupta	2 years (04/23-03/25)	On-Going Study
SPONSORED PROJECTS:				
1.	Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands *(*title modified by funding agency*)*	**Gopal Krishan (PI),** S. Singh, C. P. Kumar (retd.), M. S. Rao *BGS, UK:* Dr. Dan Lapworth Dr. Alan MacDonald Dr. Daren Goody	5 years (12/17-11/24)	On-Going Study
2.	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	**Gopal Krishan (PI & Co-coordinator)**	3 years (07/20 – 06/23)	On-Going Study
3.	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	**Gopal Krishan (PI),** MS Rao	3 years (04/21 – 03/24)	On-Going Study
4.	Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river	**Sudhir Kumar,** (Proj. Coordinator), M. K. Sharma, (PI), Suhas Khobragade, Anjali, Vishal Singh, SM Pingale, Nitesh Patidar, Surjeet Singh.	5 Years 2/05-22/047	DST

A. Internally Funded R & D Studies

1. PROJECT REFERENCE CODE: NIH/HID/R&D/2022/2

Study Title:	**Ascertaining the Efficacy of Use of State of the Art Technologies for Spring Mapping and Sustainability of Springs through Suitable Interventions**
Study Team:	S S Rawat (P.I.), Sudhir Kumar, Santosh M. Pingale, P K Mishra, D. S. Bisht and Rajesh Singh
Collaborating agencies:	Central Ground Water Board (CGWB)
Type of Study:	Internal
Duration of Study:	03 Years (July 2022 to June2025)

Study Area: The present study is being carried out for Bilangana and Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district of Uttarakhand state of India

Objectives:

1. To physically validate the springs identified by SOI using state of the art technologies in Bilangana and Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district,
2. To create web-based spring database & its regular updation,
3. To conduct water quality analysis of the surveyed springs to understand the qualitative status of the springs in the area,
4. To identify the vulnerable springs which needs to be revived, and
5. To develop the capacity of local stakeholders and implementing agencies for effective development and management of springshed programme

Progress:

1. Five Survey of India (SoI) toposheets have been digitalized and 75 springs have been identified (Fig. 1).
2. Different base maps such as Digital Elevation Map (DEM), Drainage Network, Topomaps etc has been prepared digital form for planning the survey of the springs emerging in Bhilangana block of Tehri Garhwal district.
3. A field visit was performed by the project team on 14-15.02.2023. Six springs have been geotagged, performed measurements of onsite physical parameters of springs, filled samples for detailed water quality and isotopic analysis.

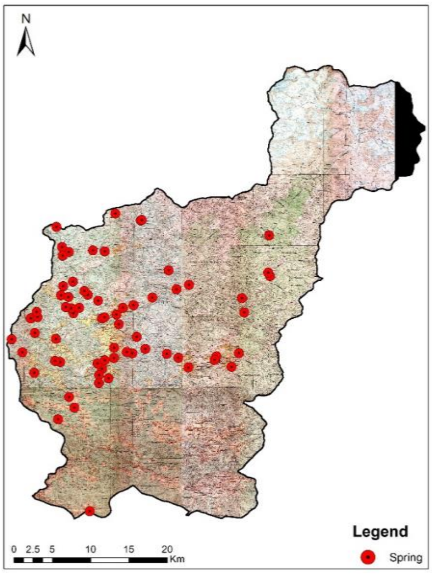


Fig. 1: Map of the Bhilanagana block of Tehri Garhwal district of Uttarakhand showing the Spring locations digitalized from SOI topo-sheets.

2. PROJECT REFERENCE CODE: NIH/HID/R&D/2022/1

Study Title:	**Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions of India**
Study Team:	SD Khobragade (PI), Dr. Vishal Singh, Scientist-C, Dr. Sudhir Kumar, Sc-G;
Type of Study:	Institute Funded R & D Study
Duration:	3 years
Date of Start:	April, 2022
Date of Completion:	March, 2025
Budget:	10 Lakh

Statement of Problem:
Evapotranspiration is one of the key components of the hydrologic cycle. Precipitation which falls on the land is subjected to evaporation and evapotranspiration before it reaches back to the oceans, causing a significant loss of the available water. Increasing scarcity of water due to increased ET losses may lead to difficulties in meeting the various demands of the growing population and its development needs. Most of the water bodies in the warm tropical regions undergo heavy evaporation losses. As per the CWC (2006) report, average annual evaporation loss from reservoirs/water bodies in India is about 27,000 MCM. As such, any change in evapotranspiration is likely to significantly affect the global hydrologic as well as energy cycle (IPCC, 2013). Being a cause of significant water loss, evapotranspiration plays a major role in determining the stream flow regime. Therefore, understanding the impact of temperature rise or climate change on evapotranspiration is essential for a proper understanding of the impact of climate change on the hydrological regime of the stream and water availability in the basin or water body. It shall provide a proper assessment of how much more or less water shall be available and, if less water is available, then how much additional water shall be required to meet the various demands. Unfortunately, not many studies have been reported on assessment of impact of climate change on evaporation and Evapotranspiration, more so for India.

Objectives:
The major objectives of the proposed study are: ·

i) To assess the present ET regime of some selected climatic regions of India
ii) To assess the impact of rising temperature on various hydro-meteorological parameters used for ET assessment
iii) To predict and compare the possible impact of climate change on ET regimes of the selected climatic regions of India

Study Area
The study is proposed to be carried out for different climatic regions of India. About five areas are to be identified to represent different climatic regions.

Brief Methodology

i) The present average ET rates for selected climatic regions of India shall be estimated from the present hydro-meteorological data of last few decades, using the Penman-Monteith model
ii) All temperature dependent hydro-meteorological paramours shall be identified.
iii) Projected climatic data variables such as minimum and maximum temperature from the latest GCMs developed under CMIP6 project shall be obtained to analyze the impact of climate change on ET factors.
iv) For this purpose, the evaluation of four best GCMs with SSP245 and SSP585 scenarios
v) (total eight scenarios) will be done for selected climatic regions and then the bias

correction and spatial downscaling of the GCM variables will be performed for selected climatic regions of India.

vi) The downscaled and bias corrected GCM variables shall be used as input to the Penman-Monteith model and future changes in ET rates will be estimated by performing probabilistic linear and non-linear trends analysis (e.g. Quantile regression, Q-Q plots, and CDF).

vii) The present and projected ET rates shall be compared to assess the impact of climate change on ET variability (in terms of magnitude of change) for different regions.

viii) The present and predicted rates of different climatic regions shall be compared and factors responsible variation shall be identified

The progress of the study shall be discussed during the WG meeting.

3. PROJECT REFERENCE CODE: NIH/HID/R&D/2022-24/3

Title of the study	:	*Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India*
Name of PI and members	:	NIH, Roorkee, India Dr. Gopal Krishan (PI) Dr. M.S. Rao (co-PI) **SKUAST-Srinagar** Prof. Rohitashv Kumar (co-PI)
Type of study	:	**Internal**
Date of start (DOS)	:	**September** 2022
Scheduled date of completion	:	**March** 2024
Location	:	**Kashmir**

Statement of the problem:

One of the main tributaries of the river Jhelum, the Doodhganga stream provides a vital source of drinking water and irrigation for the people of Budgam and Srinagar. Any contamination near recharge areas can lead to degradation of water quality in areas of discharge (streams and springs). Therefore, monitoring the water quality is a crucial issue for the sustainable management of water resources. Keeping in mind these concerns, it is important to delineate the potential recharge sites in order to prevent or at least reduce future contamination. Stable Water isotopes - hydrogen (δ^2H) and oxygen ($\delta^{18}O$) in conjunction with conventional hydrogeology and hydrogeochemistry have been shown to be effective tools for solving many critical hydrological problems (Clark and Fritz 1997; Bhat and Jeelani, 2015). Therefore, the mountain watershed of the Doodhganga River is selected for the research in this study. Combining field investigation and indoor analysis, this study will analyze the hydrogen and oxygen isotopes and hydrochemical characteristics of surface water and groundwater in the basin using environmental isotope and hydrochemical techniques. This study would discuss the effect of altitude on hydrogen and oxygen isotopes and the interaction between surface water and groundwater in the mountainous watershed of the Doodhganga River. This is of great significance for enhancing the understanding of the water cycle in mountain basins and understanding the interaction and transformation relationship between surface water and groundwater for the rational utilization and effective protection of water resources in mountainous areas, as well as preventing and controlling water pollution. This study also provides a theoretical basis for the study of the water cycle in the basin under changing environments.

Study area

Doodhganga literally means stream of milk and implies that the stream once carried water as pure as milk and as holy as the Ganges. Doodhganga catchment of Kashmir Valley located in the northern part of India between 33° 42′ to 34°50′ N and 74°24′to 74°54′ E, covers an area of 655 km². It is one of the left bank tributaries of the river Jhelum, originating on the eastern slopes of the Pir Panjal mountain range below the Tatakuti peak which is at an altitude of 4,500 m a.s.l (Hussain and Pandit 2011a, b). The topography of the watershed is varied and exhibits altitudinal extremes of 1,548–4,634 m a.m.s.l (Romshoo and Rashid 2012). The upper reaches of the catchment that is usually snow covered and has extremely steep slopes of more than 70 %, followed by comparatively lesser steep slopes of 60–70 % which reflect the different aspects of mainly the Karewa formations in the middle parts of the watershed. The downstream watershed area have very gentle slope of 0–1 % (Hussain and Pandit 2011a, b).

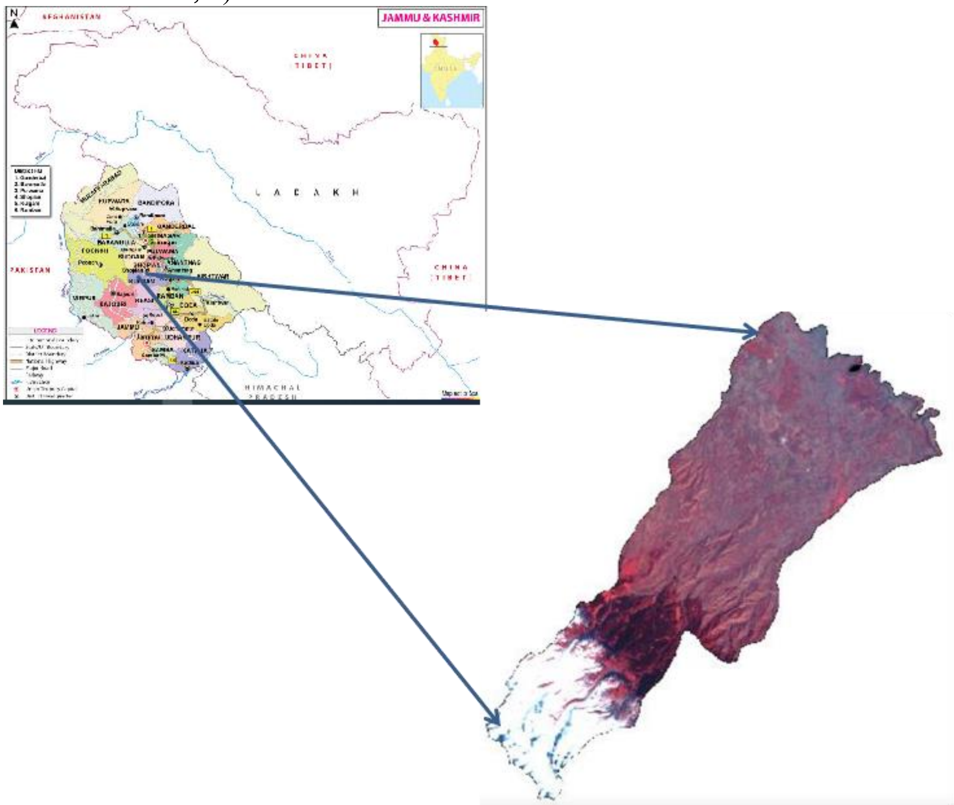


Figure – 2: Doodhganga Watershed

Whether Study is a New Study/Extension of Previous Studies: New study

Methodology:
Preliminary Work:

Base map of the study area will be digitized from the survey of India toposheet using ArcGIS 10.2 software or delineating the area using HecGeoHMS in ArcGIS platform. Precise locations of sampling points will be determined in the field and the exact longitudes and latitudes of the sampling points will be imported using a GIS platform.

Objective 1: To assess surface and groundwater quality using hydro-geochemical analysis.
Fieldwork, and collection of surface and groundwater water samples for the analysis of physio-chemical parameters and isotopic analysis will be carried out. Physical parameters (temperature, pH, total dissolved solids, and electrical conductivity) will be measured and recorded in-situ using portable instruments. Determination of major ions and trace elements

Objective 2: To characterize isotopic signatures in groundwater and surface water to delineate the sources of groundwater recharge using isotopic signatures. Stable Water isotopes - hydrogen (δ^2H) and oxygen ($\delta^{18}O$) will be analyzed

Objective 3: Delineation of the groundwater recharge zones and groundwater contamination sites / Or Assessment of groundwater contamination risk mapping.
Sources of Groundwater Recharge: The values of $\delta^{18}O$ and δ^2H measurements of precipitation and groundwater will be assessed to identify the recharge areas of groundwater. The area can be identified by measuring ^2H and ^{18}O concentrations and correlating them to the altitude at which precipitation could have infiltrated the ground.

Groundwater Contamination source assessment: The spatial variability of Hydro-geochemical and isotope values will be carried out in GIS software using geospatial analysis tool and the hotspots of aquifer contamination will be identified.

Progress

The sampling sites are identified (fig. 3) and samples are analysed for isotopes analysis

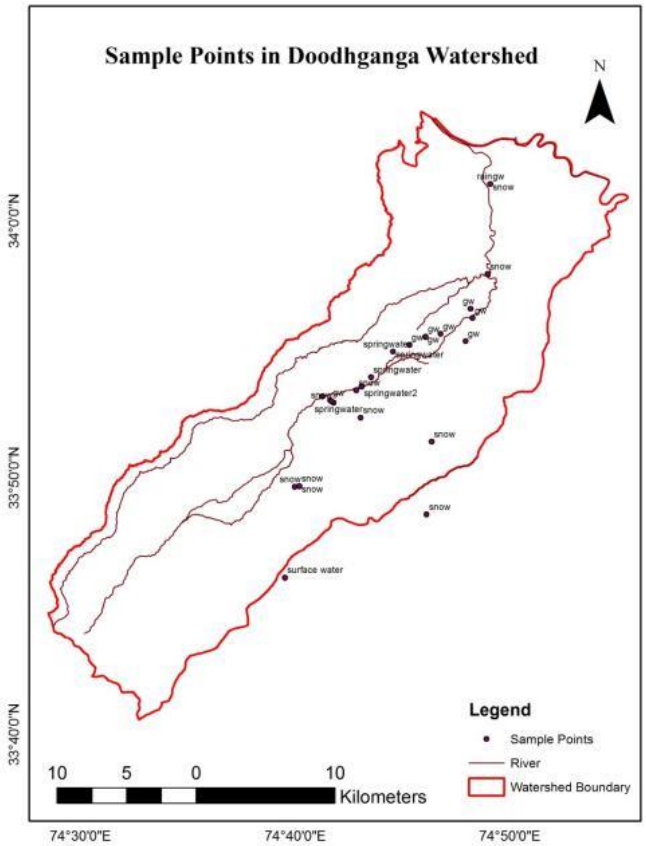


Figure - 3: Sampling sites

Action plan:

Period	September 2022 to March, 2024	Remark
September 2022 to March 2024	Collection of waters samples Analysis of the samples Data analysis and interpretation Report writing and publication	Report preparation as per Annexure 1

Study Benefits /Impact:

- Isotope characterization of water resources in the study area
- Source identification
- Surface water-groundwater interactions
- Water quality assessment
- Reports and publications

4. **PROJECT REFERENCE CODE: NIH/HID/R&D/2022/4**

Title of the study: **Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies**

Thrust Area under XII five-year plan

Sustainable water systems management: Adaptation of hydro-system to climate change

Project team: S.M. Pingale (PI), Soban Singh Rawat, S.D. Khobragade, Rajeev Gupta

Type of Study: Internal R&D study

Duration: 2 years

Statement of the Problem

The aim of this study is to understand the complexity of the different resolutions data on surface runoff and water storage capacity estimation of the rain water harvesting structures in the catchments. This study will do assessment of runoff and water storage capacity in the water harvesting structures such as check dams. The outcome will be useful for making effective Rainwater Harvesting Strategies. The quantification of errors/accuracy in the design estimates is more important for accurate and volumetric assessment and understanding the magnitude of runoff and storage capacity of the rainwater harvesting structures in the catchment. Therefore, this study will be useful for local community, policy makers, Engineers and administration for appropriate management and adopting suitable measures in making rainwater harvesting strategies in the catchments.

Objectives

General objective

The general objective of the present study is to assess the feasibility of open sources data for the estimation of runoff and water storage capacity for the rain water harvesting strategies.

Specific objectives:

The present study will be carried out with the following objectives:

6. To estimate the surface runoff in the catchments using different sources of data.
7. To develop Intensity-Duration-Frequency (IDF) curves for different return periods of rainfall and flow duration curves for sustainability analysis of the streamflow.
8. Estimation of water storage capacity of the water harvesting structures by different sources of topographic data.
9. Quantification & volumetric assessment of runoff and water storage capacity for Rainwater Harvesting Strategies.

Study area

The present study will be carried out for the selected structures and catchments considering Plain and Hilly terrain of Uttarakhand State.

Methodology

The proposed methodology has been described here:

a. The catchments will be selected where water harvesting structures are already available for its quantitative & volumetric assessment.
b. Two catchments will be selected, which represents the plain and hilly terrain for the present study.

c. The surface runoff (Peak rate and total volume) will be estimated by using Rational method and SCS curve number method.
d. These will be estimated using different sources of topographic data while other datasets will be taken same.
e. The Intensity-Duration-Frequency (IDF) curves for different return periods of rainfall and flow duration curves for sustainability analysis of the streamflow will be developed for safe design of rainwater harvesting structures.
f. The water storage capacity of the water harvesting structures will be estimated by different sources of topographic data and different hydrological modelling tools.
g. Also, quantification & volumetric assessment of runoff and water storage capacity will be carried out for making Rainwater Harvesting Strategies in the catchments.
h. Finally, suitable recommendations and appropriate sources of data will be quantified for making rainwater harvesting strategies in the catchments.

Research outcome from the project

- ✓The quantification and volumetric assessment of different sources and scale of topographical data on surface runoff estimation in terms of total volume and peak rate of runoff estimations.
- ✓Also, the accurate quantification and volumetric assessment of water storage capacity of the water harvesting structures based on different sources and scale of topographical data.
- ✓Development of IDF curves, which can be used in the safe design of hydrologic, hydraulic, and water resource systems; and flow duration curves, which can be used for estimation of dependable flows for water availability and distribution planning in the catchment area.
- ✓The outcome and procedures of estimates will be useful for Policy Makers, Engineers and Planners and various stakeholders for soil and water conservation activities in the different catchment areas.

Work Schedule:

a. Probable date of commencement of the project: April, 2023
b. Duration of the project:02 Years
c. Stages of work and milestone:

S.N.	Work Element	1st Year				2nd Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Site Selection & literature review								
2	Data collection (e.g. hydro-meteorological data, satellite imageries)								
3	Creation of GIS data base of selected sites/catchments								
4	Field data collection and survey of selected sites and catchments								
5	Collection and analysis of field data								
6	Surface runoff estimation by different sources of topographic data								
7	Development of IDF and FD curves								
8	Storage capacity estimation of water harvesting structures by different sources of topographic data								

9	Quantification & Volumetric Assessment for Rainwater Harvesting Strategies								
10	Report writing								
11	Dissemination of results/Scaling out plan								

B. Sponsored Projects

1. PROJECT REFERENCE CODE: NIH/HID/BGS/-2017_24

Title of the study	: Groundwater fluctuations and Conductivity Monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements
Study Team :	Dr. Gopal Krishan)PI(Er. C.P. Kumar (co-PI) (Retired) Dr. M.S. Rao (co-PI) Dr. Surjeet Singh (co-PI) **BGS, UK team**

Type of study	**:**	**Sponsored,** BGS, UK.
Date of start (DOS)	**:**	December 2017
Scheduled date of completion	**:**	November 2024
Location	**:**	Bist**-** Doab, and South**-**west Punjab

Statement of the problem:

Punjab is underlain by the Indus Basin aquifer which has been rated as the second-most over stressed aquifer in the world. Among all the states of India, Punjab is drawing highest amount of groundwater resulting in its declination at an alarming rate. Bist-doab is one of the important regions of Punjab comprising of the districts of Hoshiarpur, Jalandhar, Kapurthala and SBS Nagar (fig. 4). In recent years, a large volume of groundwater reported to be extracted in Hoshiarpur and Jalandhar districts. Agriculture is dependent on groundwater irrigation and concerns exist over the sustainability of current and future exploitation of groundwater; tracer data can help quantify groundwater renewal processes. In the joint study with BGS, UK high frequency water level and conductivity data is interpreted along with the analysis of water samples for a suite of tracers. In addition to the study in Bist-Doab, the study area has been extended to south-west (SW) Punjab where increasing demand of the irrigation water led to improper surface water irrigation policies resulting in water logging problems coupled with apprehension of saline zones formation by salinity ingression towards central Punjab due to excessive groundwater pumpage. To assess the inter-connection between aquifers sampling has been planned in Faridkot, Fazilka and Muktsar districts of Punjab (fig. 4).

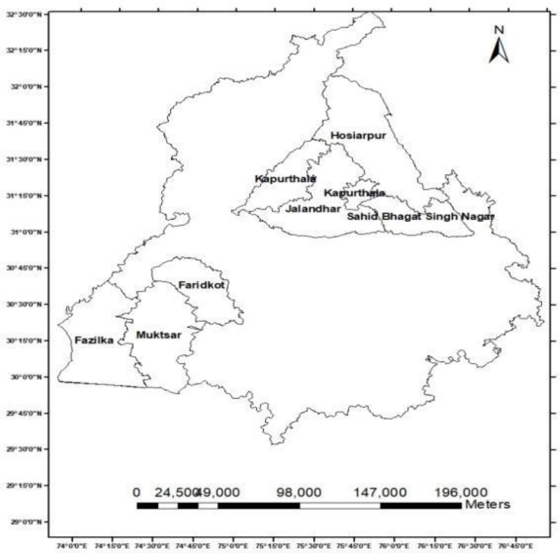


Figure – 4: Study area

Whether Study is a New Study/Extension of Previous Studies: Extension of previous studies

Methodology:

In this study, groundwater level and conductivity data are monitored and high resolution field based observations are collected. For this loggers were installed in Saroya, Bhogpur and Sultanpur Lodhi in the month of May, 2019 (Fig. 5). In addition to these sites water level loggers were installed in Bhogpur, Tanda and Nakodar in October, 2019 (Fig. 5). The groundwater samples were collected for analysis of CFC, SF6 (at BGS, UK) for better understanding of the aquifer systems from 10 sites (fig. 6) from the network of depth wise piezometers . Piezometers were developed in the depth range of 5 m-32 m and categorized as shallow (<10 m); intermediate 1st (10-15 m); intermediate 2nd (18-20 m) and deep (28-32m).

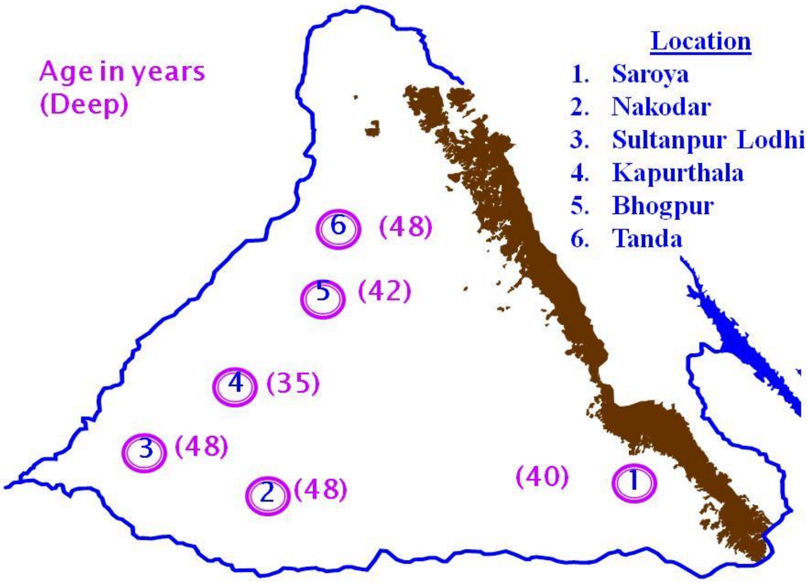


Figure – 5: Sites for installation of loggers in Bist Doab, Punjab

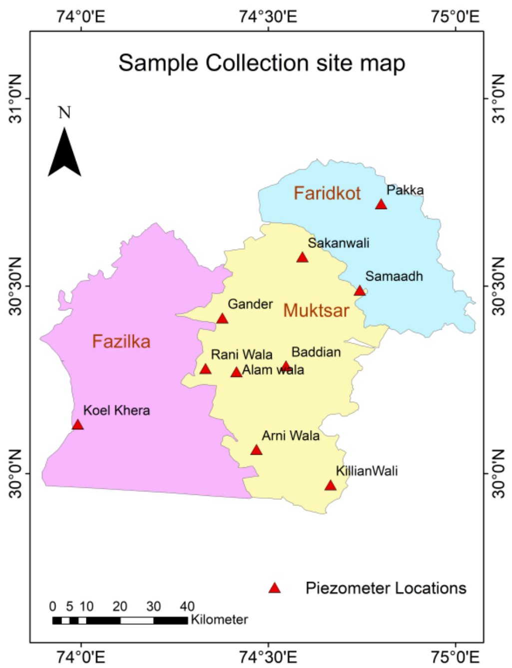


Figure – 6: Sites for sample collection in south-west, Punjab

Progress:

The samples at BGS has been analysed for CFC, SF6 and other heavy metals. The data analysis and interpretation is in progress. Future plan includes downloading data from water level loggers and conductivity loggers, collection of new data from state department from nearby piezometers, and data analysis work with respect to various parameters like rainfall, land use etc. to observe the seasonal and spatial variation

Bist-Doab

Average groundwater isotope values for shallow and deep groundwater sites are compared with amount weighted rainfall values and surface water end-members confirms the overall dominance of meteoric sources of groundwater recharge

Some of surface water samples show evidence of enrichment due to evaporative effects but average water isotope values for groundwaters do not show any evidence of evaporative enrichment relative to the GMWL or LMWL

Groundwater stable isotope time-series and pairwise comparisons show that there are significant differences between deep and shallow groundwater isotope signatures at the same locations suggest long-term shift in the groundwater isotope values and salinity over the last c.20 years based on based on groundwater residence time data or shallow groundwaters in this region.

SW Punjab

Salinity variations are observed in the different aquifers in terms of average electrical conductivity in deeper aquifers (30 m) is 5050 µS/cm; in aquifer tapped at depth of 5-8 m it is 4068 µS/cm while in middle aquifers 10-20 m the electrical conductivity is 2794-3006 µS/cm.

From the SF6 data, it is inferred that the piezometers tapped at the depth of 20-30 m are older (`50 years) as compared to the other aquifers (~30-45 years). The evidence is widespread CFC contamination but the SF6 is fine. Hence, best ‘age’ or mixing estimates come from SF6 data alone. There are varied changes such as water gets younger with the depth in some cases.

It is therefore most likely that this simultaneous change in isotope value in water samples in both deep and shallow sites is driven by changes in borehole pumping regimes that take place across the state.

Some unanswered questions are:

What is the synchronisity between deep and shallow groundwater level responses?

Do the slopes of the drawdown differ (between and within sites) – does this tell us anything about the aquifer system or just the rates of pumping or both?

Action plan:

Year	Dec. 2017 to Nov., 2024	Remark
Dec. 2017 to Nov. 2024	• Literature review on available groundwater studies including water table, water quality and other hydrogeological aspects in Punjab • Monitoring of water level and conductivity fluctuations in Bist-Doab, Punjab • Water sampling and analysis for isotopes • Prepare status report on GW issues in Punjab • Presentation of work progress in a workshop/review meeting under the project	Report preparation

2. PROJECT REFERENCE CODE: NIH/HID/BMBF/-2020_23

Title of the study:	*Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF*
Name of PI and members:	NIH, Roorkee, India Dr. Gopal Krishan (PI and co-coordinator) **University of Applied Sciences Dresden (HTW Dresden/HTWD), Germany** Prof. T. Grischek (Project Leader) Dr. C Sandhu (Project Coordinator)
Type of study:	**Sponsored,** Federal Ministry of Education and Research, Germany (BMBF)
Date of start (DOS):	**01** July 2020 (**Approval received in Feb, 22 Ministry of Jal Shakti & DEA**)
Scheduled date of completion:	**30** June 2023; extension requested upto December 31, 2023 on no cost basis
Location:	Agra, Uttar Pradesh and Phillaur, Punjab

Statement of the problem:

Background

The floodplain of the Yamuna river between the National Capital Region of Delhi and the city of Agra (located approximately 200 km south of Delhi) is one of the most densely populated urban and rural regions in India (COI, 2011). Large quantities of untreated to partially treated domestic and industrial wastewater are discharged into the Yamuna between these two cities resulting in a critical river water quality (Agarwal and Trivedi, 1995; CSE, 2002; Seth and Babu, 2007). Despite the Yamuna's poor water quality, the river is a major source of raw water for domestic purposes for towns and cities located by it, including Agra city and for irrigation in the rural and semi-urban areas (GONCTD, 2013). After direct pumping from the river, the water is conventionally treated. However most of these conventional drinking water treatment plants are technically unable to remove the high concentrations of micro-biological, organic and inorganic parameters present in the river water thereby either resulting in deliberate interruptions in drinking water production or in widespread consumer dissatisfaction due to noticeable and unacceptable organoleptic quality of the supplied water (CSE, 2002; Sandhu et al., 2011). Furthermore, there is a widespread perception amongst the consumers that the water supplied in the taps is unsafe for consumption without prior treatment at the household level. That is why many households typically use reverse osmosis filters. There are also many areas that are not connected to the piped water supply. These areas have to rely either on groundwater (vertical wells, handpumps) or water delivered in tankers that is expensive and is not affordable by many people.

By using wells installed on the banks of flowing rivers, river bank filtration (RBF) combines the advantage of easy access to large volumes of induced surface water (SW) with the benefit of an improvement in water quality due to natural treatment processes occurring during aquifer passage. Field investigations at various locations across India including in Uttarakhand and the Yamuna floodplain (Delhi and Mathura) have confirmed that there is a large potential to use RBF as an alternative to directly abstracted SW for drinking water production, primarily because it provides an ecosystem service by effectively removing pathogens and turbidity even in monsoon (Sandhu et al. 2011, 2016).

Proposed solution, technological intervention and demonstration up to 2018

In light of the previously described background and scientific investigations conducted on RBF at locations in Uttarakhand, NCR Delhi and other parts of India within the framework of the Saph Pani project (2011 – 2014) accompanied with construction of pilot RBF schemes in Uttarakhand, NIH was motivated to demonstrate RBF technology at six sites across India, including Agra, that have diverse environmental conditions within the project Peya Jal Suraksha (PJS, 2015–2018) funded by the Ministry of Jal Shakti (NIH, 2019). Consequently, the site in Agra was first investigated with standard geophysical, geotechnical and water quality investigations. Accordingly, the site was found feasible for the construction of a vertical exploratory well. The well was constructed on the riverbank in the premises of the Agra waterworks at Jeevani Mandi in February 2018. Due to the scheduled termination of PJS in 2018, only one water sample could be analysed during development of the well in 02/2018. Further investigations, including geohydraulic measurements (water levels monitored for at least one hydrological year) and water quality, could not be conducted. So it was not possible to evaluate the purification efficiency of the RBF system at Jeevani Mandi, because the system only became operational when the PJS project concluded.

Nevertheless, water quality investigations conducted at an existing high capacity horizontal RBF well in Mathura by collaborators from IIT Roorkee in 2007/2008 and subsequently by NIH Roorkee, HTW Dresden and TU Dresden at the same RBF well in Mathura and Yamuna river and near-bank groundwater from 2013 onwards in Agra and Mathura within the framework of the Saph Pani project and Indo-German Competence Centre for Riverbank Filtration (MoU NIH & HTWD, 2011) showed a high potential for RBF as a pre-treatment step for drinking water production. The main advantages of RBF in Agra-Mathura region are an improvement of organoleptic parameters (taste, odor and aesthetic appearance) and a substantial lowering of concentrations of organic compounds including dissolved organic carbon (DOC), turbidity and pathogens and a low risk of formation of disinfection by-products. The main positive observation is that while river water DOC concentrations are high and show a large seasonal fluctuation of around 9 mg/L (3 mg/L in monsoon – 12 mg/L in non-monsoon), the concentration of DOC in the RBF wells was found to be substantially lower at 3 mg/L and 6 mg/L in monsoon and non-monsoon respectively. Removal of total and fecal coliform of 1.3–1.7 and 2.3–3.2 $\log_{10}$ units respectively was observed at the high capacity RBF well in Mathura. Thus RBF can serve as an important pre-treatment step and provide cost-savings for post-treatment.

Validation, demonstration and exploitation of RBF technological intervention post 2018

With the impending conclusion of project PJS in 2018, NIH and HTWD endeavored to exploit the infrastructure created in PJS (pumping well), in a new collaborative project. The rationale for this is given below. None of the following were possible to investigate in the predecessor project PJS:

1. Validation of RBF process:
   a. Possibility to investigate the upper limit of the purification capacity for RBF w.r.t. organic micropollutants and pathogens because the Yamuna river is one of the most polluted rivers worldwide
   b. Comparison of RBF water quality with directly abstracted and conventionally treated surface water treated at the same location
   c. Investigation of the effects of aquifer anisotropy (hydraulic conductivity changes in vertical/z-direction due to intermittent low and high conductivity layers) because the subsurface stratification found in the Yamuna floodplain in Agra is similar to many locations in the Ganga-Yamuna basin
   d. Estimation of the portion of bank filtrate in pumped water from well and travel time of bank filtrate from river to well

2. Demonstration of RBF scheme:
   a. Development of existing well into a demonstration site for RBF to show how a RBF site should be made and to display the benefits of RBF
   b. Creation of infrastructure to monitor the RBF site by construction of at least 1 monitoring well

c. Demonstration of the purification capacity of RBF for conditions typical of extremely polluted rivers with complex subsurface geology

3. Exploitation of above by:
   a. Development of a science-based masterplan for RBF water supply in India using above scientific results
   b. Revision of existing guidelines on RBF into a second edition that will incorporate scientific / technical experiences of above
   c. Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra

Whether Study is a New Study/Extension of Previous Studies: New study

Methodology:

NIH has already established the abstraction well infrastructure at the site at Agra in PJS project (2015-2018) including vertical borewell with submersible pump, provision of electricity supply to pump and construction of pump house. Samples will be collected from river, RBF exploratory well, adjoining drainages and groundwater to assess the removal of emerging pollutants and pathogens. So the main focus of this project will cover validation, demonstration and exploitation aspects (discussed above), especially:

- Determination of the upper limit of removal of "emerging pollutants" by RBF
- Equipping the site with water quality monitoring infrastructure
- To equip site with promotional/information materials on research done at site

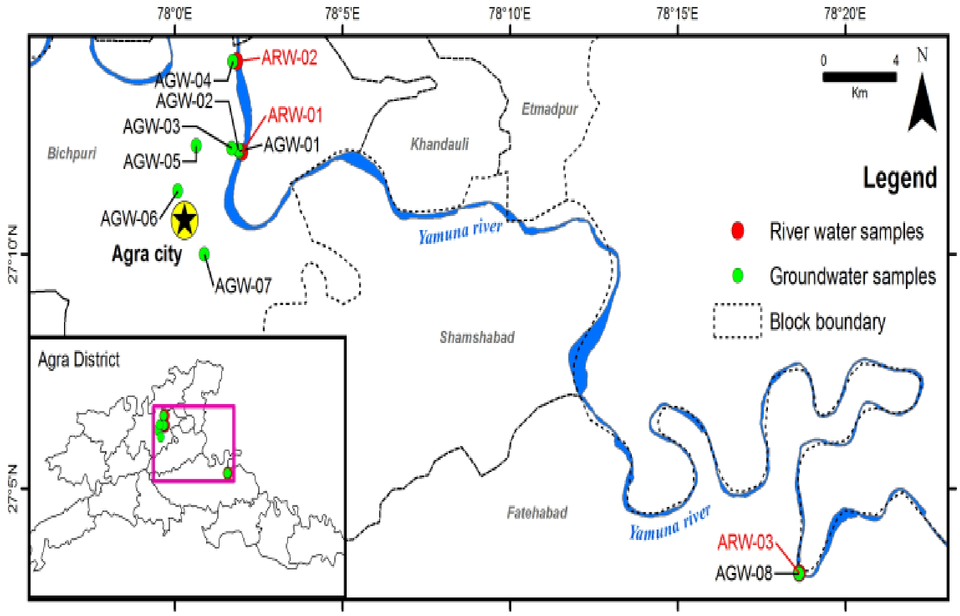


Figure – 7: Study site

Progress

1. **Work package/WP 1: Strengthening of network/collaboration**
   a. Completion of administrative formalities by signing Cooperation Agreement with 7 other Indian partners and 7 German partners in CCRBF consortium (total 15 partners).
   b. Obtaining permission from Ministry of Jal Shakti and Department of Economic Affairs, Govt. of India, for NIH to be a partner of CCRBF consortium and to participate in CCRBF project activities.
   c. Signing of Transfer Contract with HTWD (CCRBF project coordinator) to receive funds from the funding agency BMBF, Govt. of Germany.
   d. Application to MoJS to extend the existing MoU between NIH and HTWD on “Indo-German Competence Centre for Riverbank Filtration” (IGCCRBF) for third phase from 2021 to 2026.

Extension of MOU granted for 5-year period 01.06.2021 to 31.05.2026 wide MoJS letter dated 11.10.2021

e. Participation in 4 project/consortium meetings (online due to Covid-19 pandemic) on 21 July 2020, 03 February 2021, 08 July 2021 and 14 July 2022
f. Participation in online CONNECT programme meeting organized by BMBF on 18 November 2021 and 06 October 2022

2. WP2: Development of RBF demonstration site Agra

Due to the Covid-19 pandemic, especially the critical second wave from March to May 2021 and subsequent monsoon season, it was only possible to commence field work in Agra from October 2021

a. Scientific-technical support to CCRBF German partners HTWD & TUD for field investigations in Agra, liaison with stakeholder UP JAL Nigam (Oct. 2021 – Nov. 2022)
b. Collection and analyses of water samples for Oxygen-18 and Deuterium isotope
c. Co-supervision and scientific and logistic support to collaborative master thesis of:

J. Nainan (2022) Synthesis of complex hydrogeological conditions for riverbank filtration in Agra and Guwahati, India. Master Thesis, TU Dresden, Institute of Groundwater Management; HTW Dresden, Division of Water Sciences; NIH Roorkee, Groundwater Hydrology Division & BBEC Kokrajhar, Dept. of Civil Engineering.

d. Field work comprising water sampling for ions, heavy metals, dissolved organic carbon and organic micropollutants, shallow drilling with auger/tripod to determine groundwater level at site
e. Review and synthesis of literature and preparation of project reports

The key conclusions from the work in Agra are:

a. 20,000 persons of economically weaker sections of society solely receive water from RBF exploratory well. Therefore the well has a high social importance
b. Seepage of bank filtrate through silty fine sand layers possible
c. Portion of bank filtrate in exploratory well can be due to better hydraulic connection of river and aquifer upstream
d. Post-treatment of ammonium required for exploratory well water, otherwise good water quality of exploratory well

Inclusion of new project site by Sutlej river in Punjab

Additionally, and with reference to the progress report of CCRBF for the year 2021-2022, a potential RBF site in village Gagdhagara, near Talwan town by the Sutlej river in Punjab has been included in the project. This is in tune with the World Bank report (2020) on "Managing Rural Drinking Water Quality in Punjab", wherein the following have been recommended:

i. Establishment of RBF systems in Punjab as a safe long-term solution
ii. And systematic inventory of existing sites and exploration of new sites for development of RBF systems along major rivers

Thereby cooperation with an additional stakeholder, namely the Department of Drinking Water Supply and Sanitation, Govt. of Punjab, has also been initiated.

Consequently, the quality of the Sutlej river water and groundwater from a vertical well used for rural water supply and located ~200 m from the riverbank in Gagdhagara, were investigated within the CCRBF project in June 2022 with the following key results and conclusions:

a. current investigations in Gagdhagara by NIH & German partners HTWD and TUD reaffirm recommendations of World Bank report (2022, points i & ii above).
b. inorganic water quality of well within IS 10500 limits for drinking water
c. little to no removal of atrazine and carbamazepine during subsurface passage indicates river-aquifer hydraulic connection
d. potential for RBF at existing site exists, however further geohydraulic investigations and water quality monitoring needed
e. good example of RBF as a sustainable source in Jal Jeevan Mission

3. **WP3 to WP5: Guideline for RBF in India (WP3), Education & Training (WP4) and RBF masterplan (WP5)**

Results from WP2 are being synthesized into these WPs and accordingly disseminated/exploited.

4. **WP6: Dissemination and exploitation of results**

NIH contributed/disseminated for the period 01 July 2020 to 31 December 2022 as follows (details in annexure II):

- 11 conference presentations (annexure II, s.no. 1 to 11)
- 2 ad hoc/workshop presentations, including at a meeting with Ministry of Jal Shakti, New Delhi and Department of Water Supply and Sanitation, Govt. of Punjab, Chandigarh (annexure II, s.no. 12 & 13)
- 1 brainstorming session organized by Uttarakhand State Council for Science & Technology (UCOST), Dehradun, 31.07.2021 (annexure II, s.no. 14)
- 2 peer-reviewed book chapters published (annexure II)
- 7 conference abstracts included in proceedings, 1 article in India's leading water industry publication "Everything About Water"

Action plan:

The project has been delayed due to the Covid-19 pandemic. Accordingly, the CCRBF project coordinator HTW Dresden (HTWD) submitted an application to the funding organization (BMBF) for project extension up to at least 31 December 2023 and if possible up to 31 March 2024 on a cost-neutral basis. According to DLR, the project management agency of BMBF, extension up to 31.12.2023 can be granted in principle. For this HTWD is presently preparing a detailed application for project extension.

Period	**July 2020 to June, 2023** (Annexure 1**)**	**Remark**
July 2020 to June 2023	Monitoring of the site regularly Establishing the site with monitoring infrastructure Project works as listed in section "Validation, demonstration and exploitation of RBF technological intervention post 2018" Preparation of revised RBF guidelines and masterplan on RBF for India Prepare a status report Participation of NIH in 3rd International Riverbank Filtration Conference in Dresden from 13.– 15.06.2023 Participation of NIH in CCRBF project meeting in Dresden on 16.06.2023	Report preparation as per Annexure 1 and dissemination activities as per Annexure 2
01 July 2023 to 31 March 2024	Field work and water sampling during monsoon season Preparation of input for RBF guidelines and masterplan Organisation of a final project conference in February 2024 (subject to project extension)	Subject to project extension

Strategic linkages for further work and follow-up

- Discussions with GiZ representative at the 5th India-EU Water Forum, New Delhi, 27 Oct. 2022, for advancement of activities on RBF in India. Further discussion planned.
- Discussions with representative of Haryana Water Resources Authority at Internal Ground Water Conference, Roorkee, 02. – 04.11.2022 for advancement of activities on RBF in Haryana. Further discussion planned.
- Discussions with Department of Water Supply & Sanitation, Govt. of Punjab for advancement of activities on RBF in Punjab. Further discussion planned.

Study Benefits /Impact:

- The result will be the creation of a road map within framework of RBF masterplan to increase contribution of RBF to total drinking water supply from currently less than 1% to at least 5% by 2030.
- Strengthening Indo-German/European scientific collaboration on managed aquifer recharge/RBF
- The project has a high socio-economic relevance for the underprivileged households living in Jeevani Mandi area of Agra because before implementation of the action they had no access to safe drinking water and after implementation of action they have access to safe drinking water.
- informing and collating experiences/knowledge; capacity development and strengthening competence on MAR/RBF.
- evaluating existing work bases and sharing or making them known within the network synergies with other Indo-European projects (e.g. DST–EU-Horizon2020 funded projects).

Specific linkages with Institutions:

- German partners: HTWD, TZWD, TUD, FHP, AUT, AKUT, GiZ (to be intensified)
- Indian partners: UJS, BHU, CSIR-CMERI, BBEC, AU, IITM, TERI, UPJN

Future plan

- Use of synergies from the competence-pool of RBF/CW/MAR through training and thematic cooperation between partners and stake holders
- Possible extension of CCRBF project up to 31 March 2024.

3. PROJECT REFERENCE CODE: NIH/HID/DST-SERB/-2021_24

Title of the study : *Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen*

Name of PI and members :
NIH, Roorkee, India
Dr. Gopal Krishan (PI)
Dr. M.S. Rao (co-PI)
IIT-Kanpur
Dr. Shivam Tripathi (PI)
Dr. Richa Ojha (Co-PI)
Dr. Rajesh Srivastava (Co-PI)
Dr. Saumen Guha (Co-PI)

Type of study : **Sponsored,** DST-SERB

Date of start (DOS) : April 2021

Scheduled date of completion : March 2024

Location : NIH Roorkee and IIT-Kanpur

Statement of the problem:

Agriculture is the single largest user of freshwater in India. A significant portion of the applied irrigation water eventually evapotranspires. The transpiration (T) component of the evapotranspiration (ET) is associated with crop productivity, while the undesirable soil evaporation (E) component represents losses. The knowledge of the relative magnitudes of E and T fluxes is therefore essential for designing efficient irrigation techniques and understanding energy and moisture transfer in the soil-plant atmosphere continuum. In this direction, the institute has developed methodologies for collection of air moisture samples, soil evaporation and evapotranspiration samples, transpiration samples. Wherever possible, instruments are designed and fabricated inhouse to suit the local conditions and give reliable data at a low cost. For experimentation in the field, two sites are selected in Kanpur to study ET partitioning at plot and field scales. The sites are instrumented for measuring ET fluxes using hydrometric and isotopic methods.

Whether Study is a New/Extension of Previous Studies: Extension of previous study

Progress

As part of the project, the following work has been completed at the NIH-Roorkee to date:

1. **Collection of Atmospheric moisture samples**

We used the cone-condensation technique to collect atmospheric moisture samples. Using the 8 screws provided, the aluminium cone was positioned so that the tip of the cone was directly just above the bottle and the moisture droplets condensing on the surface of the cone fell directly onto the bottle.

2. **Collection of Plant transpiration samples**

Water is dispersed into the atmosphere via the stomata and can be collected using transpiration bags. Plant transpiration samples were collected using transpiration bags.

S.No.	Common Name	Scientific Name
1	Ashoka tree	Saraca asoca

2	Indian laurel	Terminalia elliptica
3	Jamun tree	Syzygium cumini
4	False Ashoka Tree	Polyalthia longifolia

3. Model development to collect Soil evaporation samples

Our current model for collecting soil evaporation samples is made of a clear Acrylic Sheet and lists the following features:

I. Experiment set up made of transparent Acrylic Sheet (5 mm thickness) with dimensions 75*75*60 cm.

II. Air compressor for suction and trapping evaporated vapors in the glass tube (where these vapors can be condensed). The compressor is connected to a rotameter and nozzle valve to control the suction and trap process.

III. The mixture of Liquid nitrogen and acetone for condensing vapors.

IV. Wireless Bluetooth data logger and sensor to know humidity and temperature variations inside and outside the experimental setup.

An air compressor was used to suction and trap the vapors in the glass tube (where these vapors were condensed). The suction process occurred at a rate ranging from 3 lt/min to 5 lt/min. The volume of the sample collected was found proportional to the suction rate.

4. Collection of Rainwater samples

A Standard non-recording rain gauge prescribed by the IMD (Symon's rain gauge) was used to collect the rainwater samples. The gauge consisted of a funnel with a sharp-edged rim of 127 mm diameter, a cylindrical body, a receiver with a narrow neck and handle, and a splayed base that was fixed in the ground. The rain falling into the funnel was collected in the receiver kept inside the body and measured using a special measure glass which was graduated in mm. The gauge was fixed on a concrete foundation of size 60 cm x 60 cm x 60 cm which was sunk into the ground. The rainwater samples were also used to develop the LMWL for the region.

5. Collection of Groundwater samples

Standing water within a bore is exposed to atmospheric conditions and can undergo changes to its physical and chemical characteristics and is not representative of the water in the aquifer.

Unless aquifer quality is known to be vertically uniform, samples collected may include a mixture of groundwater entering the borehole using the open or screened casing methodology and can be considered to produce a composite sample or one of approximately average composition.

We observed a large isotopic variability in the atmospheric moisture ($\delta^{18}O$ = -5.25‰ to -28.59‰; δD = 1.68‰ to -127.01‰), which is most likely due to seasonal variations in the source of atmospheric moisture. The isotope values in rain samples ranged from $\delta^{18}O$ = -5.52‰ to -11.21‰; δD = -30.75‰ to -86.74‰, while groundwater samples showed the least variations ($\delta^{18}O$ = -7.14‰ to -7.40; δD = -50.04‰ to -52.28‰) in their isotopic values. The observed enriched isotopic values of transpiration samples may be explained by isotopic enrichment controlling factors such as relative humidity, temperature, and the internal and external ambient environment of the leaf. With further investigation, the data collected in this study can be useful for understanding the factors responsible for seasonal variability in isotopic values of evapo-transpired moisture.

Work done at IIT Kanpur

Experiments are being conducted at two sites, one inside IIT Kanpur and the other 15 km north of IIT Kanpur at Bithoor. Instruments are installed at both the sites to measure hydro-meteorological parameters, and the soil properties of the sites are characterized. Two sets of experiments have been performed for the Kharif season (rice; 2021-22 and 2022-23 cropping seasons) and one set for Rabi season (wheat; 2022-23 cropping season). Experiments for the second Rabi season are in progress.

A locally developed late sown wheat variety K7903 (Halana) and a locally popular hybrid rice variety DuPont Pioneer (PHB 71) are used in the experiments. Weighing-type mini-lysimeters are designed and installed at both the sites to measure E and ET fluxes. In addition, sensors have been deployed to measure temperature, relative humidity, rainfall, and wind speed & direction.

We have compared various soil and plant water extraction techniques, namely, rotatory vacuum evaporator, azeotropic distillation, displacement fluid centrifugation, and cryogenic vacuum distillation, and have standardized protocols for each technique. Further, for each experiment set, we have collected samples of soil, plant, irrigation water, river water and atmospheric water for multiple days during the cropping season for isotopic analysis. For estimating interception losses, we have used catch-cans and tipping bucket rain gauges. We have also developed a method to collect stem flow by using a centrifuge tube wrapped around the wheat stem.

Action plan:

Period	**April 2021 to March, 2024 (**Annexure 1**)**	**Remark**
April 2021 to March 2024	Installation of instruments Collection of waters samples, isotope analysis Data analysis and uncertainty quantification Data dissemination and report writing	Report preparation

Study Benefits /Impact:

1. Diurnal, inter- and intra- cropping seasonal variations in soil evaporation (E), plant transpiration (T) and evapotranspiration (ET) fluxes at the study sites.
2. A methodology to quantify uncertainty in ET partitioning. In addition, the results obtained and methodology developed during the proposed project will be useful for - (a) validating process based hydrological models that estimate E and T fluxes separately, and (b) improving irrigation efficiency by developing agricultural practices that reduce soil evaporation losses.

4. Study Title: **Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river**

Study Team: Dr. Sudhir Kumar, (Project Coordinator), Dr. M. K. Sharma, (Principal Investigator), Dr. Suhas Khobragade, Ms. Anjali, Dr. Vishal Singh, Dr. SM Pingale.
Collaborating agencies: IIT Kanpur
Type of Study: Sponsored by DST (under DST-NOW call)
Funding Agency: Department of Science and Technology, GoI
Budget: Rs**.** 240 lakh
Duration of Study: 05 Years **(**April 2022 to March 2027)

Objectives

This research aims at providing scientific understanding on the hydrological functioning and the impact of agricultural water management of the Hindon subbasin of the Ganges river. Three areas of research are distinguished:

1) Integrated water systems analysis to understand the spatio-temporal relations between surface water and groundwater quantity and quality, and the impact of human activities and climate characteristics by setting up a monitoring network.
2) Interventions to improve agricultural water management and reduce negative impacts on water quantity and quality.
3) Develop recommendations for improvements in Hindon basin water quantity and quality, food production and economic revenues.

Statement of the Problem

River Hindon, an important tributary of river Yamuna flowing through the districts of Western Uttar Pradesh, is subjected to varying degree of pollution caused by numerous untreated and/or partially treated waste inputs of municipal and industrial effluents**.** The toxic pollutants from these wastes will ultimately reach the ground water and enter in the food chain posing a threat to human health because of their carcinogenic nature**.** The pollution matrix in some stretches of the river becomes so complicated that anaerobic and septic condition prevails during the lean period due to discharge of effluents to the river from various industries and municipal areas**.** Though a large number of studies, to understand the pollution aspects of river Hindon, have been carried out by different workers (Verma and Mathur, 1971; Verma and Dalela, 1975; Verma et al., 1980; Patel et al., 1985; Singhal et al., 1987; Joshi et al., 1987; Seth, 1991; Seth and Singhal, 1994; Khare, 1994; Kumar, 1994; Lokesh, 1996; Jain, 1996, 2000; Kumar, 1997; Jain and Ali, 2000; Jain and Ram, 1997a, 1997b; Jain and Sharma, 2001a, 2002, 2006; Jain et al., 1997, 1998a, 1998b, 2002, 2003, 2004a, 2004b, 2005, 2007; Sharma, 2001; Sharma et al., 2009a, 2009b), but no comprehensive and holistic plan for rejuvenation of river has been attempted. This requires monitoring of water resources and pollutants within the river basin through data collection, modeling of river water and groundwater interaction and interpretation. Further hydrological study of the basin is important to understand the surface and groundwater interaction. Water Balance in Hindon River Basin will provide water allocation for different sectors for better water management in the basin. Reach-wise recharge augmentation plan may be implemented by identification of affluent and effluent sections in the river.

Approved Action Plan/Methodology

i) Literature review and collection of data from published reports and papers.
ii) Procurement of secondary data required for the analysis from various govt. agencies (discharge, rainfall, landuse/landcover, lithology, ground water level, aquifer parameters, sediment concentration, other water quality parameters, soil map etc.)
iii) Monitoring of water quality of River Hindon monthly basis for one year
iv) Study the relationships between different hydrological parameters

v) An inventory of pollution sources contributing to the River will be prepared from the collected information and Major Contaminant zones will be identified.
vi) Identification of affluent and effluent sections of River Hindon.
vii) Water Balance of Hindon River Basin using SWAT-MODFLOW model
viii) Reach-wise Recharge augmentation plan will be suggested

11. Work schedule / Timeline

Year	**Month**	**Consortium Activity**	**NIH action plan**
2022-23	Apr - Jun, 2022	Preparatory activities like approvals etc.	• Hiring of Project staff • Meetings with IIT K for formulating plans for field Visits • Forwarding request to state govt. for data • Literature Review
	Jul - Sep, 2022	Start of the project Kick of Meeting Hiring of Staff, PhD Creation of Advisory Board	• Administrative Approval for Equipment • Kick off Meeting and formal introduction of the members involved, role and responsibilities allocation. • Combined field visit of IIT K and NIH for G&D site and piezo-site locations.
	Oct - Dec, 2022	• Designing Observational Network • Identification of farms, urban and industry locations	• Installation of Piezometers and G&D sites • Inventory of pollution sources • Survey for morphometric analysis of river Hindon • Health, Agricultural and drinking issues identification.
	Jan - Mar 2023	Stakeholders Identification Installation of Base network and bathymetry Measurement	• Creation of Pollution Inventory • Stakeholders Identification • Groundwater level trend analaysis • Water quality over years inventory
Year-2 2023-24	Apr - Jun, 2023	Field investigations	• Soil, Groundwater and river water quality sample collection and analysis
	Jul - Sep, 2023	Data preparation for IHE-FEWS	• Contribute to FEWS data platform
	Oct - Dec, 2023	• Stakeholders Meeting • Field investigations	• Stakeholders Meeting • River discharge and water quality, • Groundwater levels and water quality
	Jan - Mar 2024	Report writing	• Preparation of Interim report • Scientific paper writing
Year-3 2024-25	Apr - Jun, 2024	Data collection	• Groundwater and river water quality sample collection and analysis

	Jul - Sep, 2024	Groundwater Investigation	• Recharge Estimation for Hindon river Basin • Estimation of Parameters for Groundwater Model Development.
	Oct - Dec, 2024	Mid- Project stakeholders meetings	• Stakeholders Meeting
	Jan - Mar 2025	Data interpretation and Report writing	• Preparation of Interim report • Scientific paper writing
<u>Year-4</u> 2025-26	Apr - Jun, 2025	Data collection	Groundwater and river water quality sample collection
	Jul - Sep, 2025	Sample analysis	Groundwater and river water analysis
	Oct - Dec, 2025	Scientific Advisory Board Meetings	Final Groundwater-surface water interaction Model
	Jan - Mar 2026	Stakeholders Workshop Result sharing and analysis	Effluent and affluent zone identification. And integration of individual developed models
<u>Year-5</u> 2026-27	Apr - Jun, 2026	Development of GW Model	Development of GW Model
	Jul - Sep, 2026	Calibration and Validation of the model	Calibration and Validation of the model
	Oct - Dec, 2026	Data analysis and interpretation	Suggestions and measures for Hindon rejuvenation
	Jan – Mar, 2027	Advisory Board Meetings for project finalization	Working on finalization of results with Dutch Partners.

12. Analysis & Results:

- Purchase of Equipment and Services Completed.
- Collection of 158 groundwater Samples
- Collection of River Water samples for water quality analysis.
- Three field Visits to river Hindon
- One workshop for aligning the thoughts and expectation. Held at New Delhi, During 15th Feb,2023.

13. Future Course of work

- Installation of Soil-moisture Probes.
- Piezometer Construction and Installation
- Construction of Various G&D sites.
- Field Investigation and sample collection.

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. A K Lohani	Scientist G & Head
2	Dr. S K Singh	Scientist F
3	Dr. P C Nayak	Scientist F
4	Dr. Sanjay Kumar	Scientist F
5	Dr. Ravindra Vittal Kale	Scientist E
6	Dr. L N Thakural	Scientist E
7	Er. J P Patra	Scientist E
8	Sri Om Prakash	Scientist B
9	Ms. Richa Pandey	Scientist B
10	Dr. Soumya Ranjan Sahoo	Scientist B
11	Sri. Gaurav Kumar	RA

APPROVED WORK PROGRAM FOR THE YEAR 2022-23

COMPLETED STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/19-23	Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP)	P C Nayak Y.R.Satyaji Rao A.K. Lohani B. Venkatesh A. R. S. Senthil Kumar T. Thomas	3 year (Sept 2019 to Nov 2022) Completed

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/20-23 MoE-STARS/STARS-1/743	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts (Funded under STARS by MHRD, GoI)	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI)	03 years (July, 2020 – June, 2023) *(Transferred from WHRC Jammu to SWHD NIH Roorkee*)

COMPLETED STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/20-22	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.	J.P. Patra Pankaj Mani A.K. Lohani Sunil Gurrapu Rakesh Kumar	2 years (July 2020 to August 2022) Completed
2.NIH/SWHD/21-23	Uncertainty in rating curves and discharge estimation	Sanjay Kumar L. N. Thakural Sunil Gurrapu N.K. Bhatnagar J P Patra	2 Years **(**April 2021 to March 2023) Completed
3.NIH/SWHD/22-22	Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A	S.K. Singh	Six month (April 2022 to 31 March2023) Completed
4.NIH/SWHD/22-23	Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution	S.K. Singh	Six month (Oct. 2022 to March 2023) Completed

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/22-24	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	A. K. Lohani R. K. Jaiswal J.P. Patra P. C. Nayak Vishal Singh	Two Years April 2022 – March 2024
2.NIH/SWHD/22-24	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak A. K. Lohani J. P. Patra Sunil Gurrapu T. Thomas Om Prakash Jatin Malhotra	3 Year (July 2022 to June 2025)
3.NIH/SWHD/22-25	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	L. N. Thakural M. K. Shama R. K. Jaiswal J. P. Patra P. K. Mishra Nitesh Patidaar N. K. Bhatnagar Jatin Malhotra Anil Kumar Chhangani	2 Year (July 2022 to June 2024)
4.NIH/SWHD/22-24	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P.Patra A. K. Lohani Pankaj Mani P. C. Nayak Sanjay Kumar Jatin Malhotra	3 Year (April 2022 to March 2025)
5.NIH/SWHD/22-25	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade P.K. Mishra Sunil Gurrapu	3 years (April 2022 to March 2025)
6.NIH/SWHD/22-23	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar Jyoti Patil Rohit Sambare Charu Pandey	1.5 Year (May 2022 to Oct 2023)
7.NIH/SWHD/21-24	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin	R. V. Kale A. K. Lohani J. P. Patra D. Khurana	03 Years (September 2021-October 2024)

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-24

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/20-23 MoE-STARS/STARS-1/743	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts (Funded under STARS by MHRD, GoI)	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI)	03 years (July, 2020 – June, 2023) *(Transferred from WHRC Jammu to SWHD NIH Roorkee*)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/22-24	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	A. K. Lohani R. K. Jaiswal J.P. Patra P. C. Nayak Vishal Singh	Two Years April 2022 – March 2024
2.NIH/SWHD/22-24	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak A. K. Lohani J. P. Patra Sunil Gurrapu T. Thomas Om Prakash Jatin Malhotra	3 Year (July 2022 to June 2025)
3.NIH/SWHD/22-25	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	L. N. Thakural M. K. Shama R. K. Jaiswal J. P. Patra P. K. Mishra Nitesh Patidaar N. K. Bhatnagar Jatin Malhotra Anil Kumar Chhangani	2 Year (July 2022 to June 2024)
4.NIH/SWHD/22-24	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P.Patra A. K. Lohani Pankaj Mani P. C. Nayak Sanjay Kumar	3 Year (April 2022 to March 2025)
5.NIH/SWHD/21-24	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin	R. V. Kale A. K. Lohani J. P. Patra D. Khurana	03 Years (September 2021-October 2024)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/23-25	Estimation of confidence intervals of index flow duration curves	Sanjay Kumar, Sunil Gurrapu L. N. Thakural J. P Patra	02 Years (April 2023 to March 2025)
2. NIH/SWHD/23-24	Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels	Sushil K. Singh	One Year (April 2023 to March 2024)

ONGOING STUDIES (SPONSORED)

1. Project Code: MoE-STARS/STARS-1/743

Title of the Project:	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate-induced impacts
Project Team:	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI, NIH Roorkee)
Collaborating agency	IIT Kharagpur
Type of Study	Sponsored by MoE under STARS Project
Duration	4 years
Date of Start	July 2020
Date of Completion	June 2024
Budget	56 Lakh (IIT KgP)

Statement of Problem

The inter-state Brahmani-Baitarani river basin is the second largest in Odisha which has undergone rapid industrialization and mining activities with the issues of flood havocs during monsoon season and reduced low flows during non-monsoon periods. This coastal river basin of the Bay of Bengal is flood prone due to its flat low-lying topography with flash floods, highly meandering dendritic drainage pattern, backwater effects from sea-surges, climate induced extreme precipitation and tropical cyclone, sea level rise, subjective reservoir operation, increased upstream river flux due to rapid urbanization, shifting cultivation practices, and floodplain encroachment reducing the river carrying capacity. Therefore, to aid for operational flood disaster management, this study proposes to develop a short-to-medium-range flood forecasting system accounting for all the aforementioned factors for an accurate real-time flood vulnerability mapping of the coastal Brahmani-Baitarani river basin. This method involves mapping of the delta region taking into account compound effect of rainfall, storm surge and upstream discharge.

Objectives:

a) Assessment of historical flood inundation and sedimentation scenarios in the study area through field survey, secondary data, and remote sensing approaches
b) Detection of historical changes in land use and river cross-sections due to sedimentation and anthropogenic activities using survey data and satellite imageries
c) Forecasting of inflows into and releases from the Rengali/Mandira reservoirs in real-time up to 10-days lead-time accounting for the effects of urbanization, paddy land use, and river sedimentation
d) Forecasting the tidal effect / sea-surges at the river-ocean confluence in the Bay of Bengal
e) Simulation of real-time 2-D flood inundation mapping in the deltaic river basin considering upstream streamflow forecasts, stream-aquifer exchange fluxes, and downstream tidal /sea-surge forecasts up to 10-days lead time.
f) Development of flood vulnerability maps in real-time (up to 10-days advance) for operational flood management using UNESCO-IHE guidelines

Brief Methodology

This study can be separated into four major categories viz., Land-surface process modeling, reservoir modeling, coastal flood plain dynamics, and ocean melding. In land-surface modeling SWAT Pothole model will be used with an error correction sub model to improve the streamflow forecast for future time period with different lead periods. Then streamflow information will be used in the reservoir operation modeling to reduce the flood peak and hydropower generation. Further the simulated release from the reservoir will be used for flood mapping in the delta region of the Brahmani-

Baitarani River basin by accounting the tidal surge generated using ADCIRC+SWAN. The vulnerability map will be generated for different lead-time taking into account the UNESCO-IHE guidelines.

Study Area

The study area consists of the Brahmani and Baitarani River basins (Figure –1), extends over the states of Odisha, Jharkhand and Chhattisgarh having an area of 51,822 km^2 which is nearly 1.7% of the total geographical area of the country with a maximum length and width of 403 km and 193 km. It lies between 83°55’ to 87°3’ East longitudes and 20°28’ to 23°38’ North latitudes. The basin is bounded by the Chhotanagpur Plateau on the north, by the ridge separating it from Mahanadi basin on the west and the south, and by the Bay of Bengal on the east. The Brahmani sub basin covers 39,033 km^2 and has a long sausage shape.

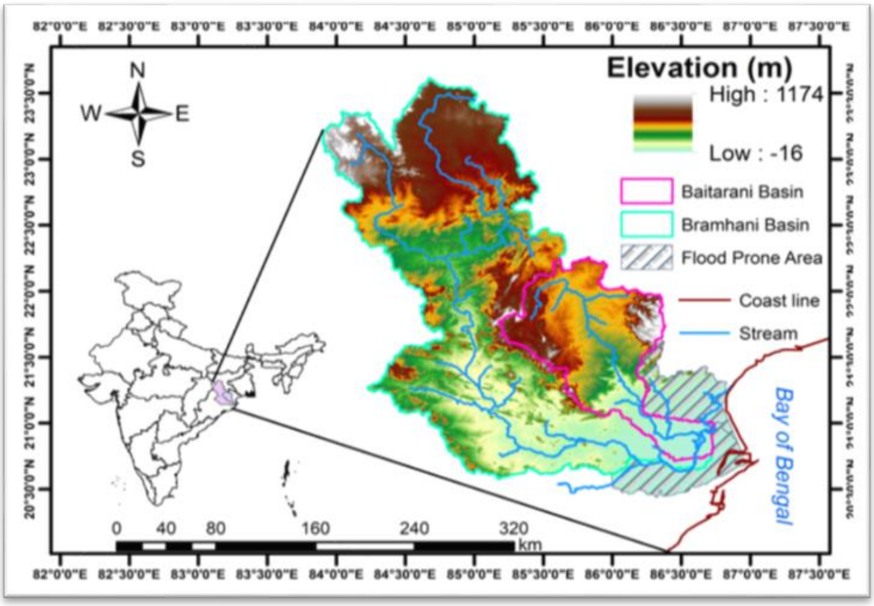


Figure –1. Elevation map of the Brahmani and Baitarani River basins.

The Baitarani sub-basin extends over 12,789 km^2 and is roughly circular in shape. The Brahmani, known as South Koel in its upper reaches, rises near Nagri village in Ranchi district of Jharkhand at an elevation of about 600 m. The river has a total length of 799 km. In its tail reach, the river is known as Maipura. The Baitarani River rises near Dumuria village in the hill ranges of Kendujhar district of Odisha at an elevation of about 900 m and has a length of about 355 km. The river is known as Dhamra in its lower reaches. The important tributaries of Brahmani joining it from left are the Karo, and the Sankh whereas the Tikra joins from the right. The main tributaries of Baitarani joining from the left are the Salandi and the Matai. Brahmani and Baitarani form a common delta area before outfalling into the Bay of Bengal. The major part of the basin is covered with agricultural land accounting to 52.04% of the total area and 2.95% of the basin is covered by water bodies. The basin spreads over 16 parliamentary constituencies (2009) comprising 10 of Odisha, 4 of Jharkhand, and 2 of Chhattisgarh.

Action Plan

Milestone/ Activity	July-Dec 2020	Jan-Jun 2021	July-Dec 2021	Jan-Jun 2022	July-Dec 2022	Jan-Jun 2023	July-Dec 2023	Jan-Jun 2024
Objective-1								
Objective-2								
Objective-3								

Objective-4								
Objective-5								
Objective-6								

Achievements vis-à-vis Objectives

Objectives	Achievements
Assessment of historical flood inundation and sedimentation scenarios in study area through field survey, secondary data, & remote sensing approach	Completed
Detection of historical changes in land use and river cross-sections due to sedimentation and anthropogenic activities using survey and satellite data	Completed
Forecasting of inflows into and releases from the Rengali/Mandira reservoirs in real-time up to 10-days lead-time accounting for the effects of urbanization, paddy land use, and river sedimentation	completed
Forecasting the tidal effect / sea-surges at the river-ocean confluence in the Bay of Bengal	Completed
Simulation of real-time 2-D flood inundation mapping in the deltaic river basin considering upstream streamflow forecasts, stream-aquifer exchange fluxes, and downstream tidal /sea-surge forecasts up to 10-days lead time.	In-progress
Development of flood vulnerability maps in real-time (up to 10-days advance) for operational flood management using UNESCO-IHE guidelines	

Progress of work

Objective (a)

Task #1: Collection and analysis of historical flood data over the Brahmani-Baitarani delta

- One SRF has been posted
- Secondary data collection and remote sensing data procurement is completed
-

Task #2: Procurement and analysis of meteorological data and satellite imageries

- In order to assess the flooding due to extreme monsoon-precipitation, daily data at all available rain gauge stations as well as event-scale sub-hourly precipitation data are procured from 8 meteorological stations. For the flood mapping of historical events, the LISS-III and LISS-IV, SAR data for selected historical flood event has been procured from NRSC. The input data required for modelling for all the main revisors in Brahmani- Baitarani river system has been collected and processed. Further, the radar data available for the coastal area will be collected. Some of the other required data has been already procured/collected from respective government agencies.

Task #3: Preparation of Flood Maps of recent flood events

Satellite imageries were processed to determine the flood-affected areas during the recent floods in the basin. For this, the events of May 2021, July 2017, and July 2015 were chosen based on the availability of Sentinel satellite imageries. The results of the satellite image-based flood inundation mapping are presented in **Table –1** in the form of total inundated area and inundated crop area.

Table 1 Selected historical flood events in the Brahmani and Baitarani basin delta

Date	Total inundated area (km^2)	Crop area inundated (km^2)
15 July 2016	1054.8	719.6
25 July 2017	1471.8	819.1
25-26 May 2021	136.0	27.2

Concluding Remarks of Objective #a: It is evident that there is a frequent occurrence of floods in the coastal region of Brahmani and Baitarani Basin. In the last 5 years, three major floods have occurred in the coastal plains creating major damages to the property and life. Flood event occurred in the month of July in 2016 inundated nearly 1054 Km^2 of landmass including cropland of 719 km^2. After a gap of 1 year, another major flood took place affecting a total landmass of 1471 km^2 including cropland of 819 km^2. Recently in May, 2021 the flood was caused due to cyclone 'Yaas', inundating 136 km^2.

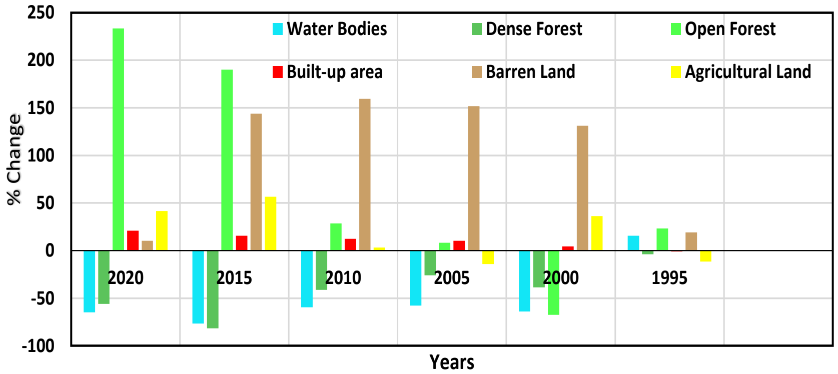
Objective (b)

Task #1:

- The CartoDEM with10 m resolution has been procured from NRSC.
- Work on historical change in river cross sections is going on.

Task #2: Preparation of Land Use and Land Cover Map

Anthropogenic activities have substantially changed natural landscapes, especially in regions that are extremely affected by population growth and climate change such as the Eastern part of India. Understanding the patterns of land-use and land-cover (LULC) change is important for efficient environmental management, including effective water management practice. Using remote sensing techniques and geographic information systems (GIS), this study focused on changes in LULC patterns of Brahmani and Baitarani River Basins for over 30 years. Multi-temporal satellite imageries of the Landsat series were used to map LULC changes. The LULC map is divided into 6 classes, i.e. Water bodies, Dense forest, Open forest, Built-up area, Barren land, and Agricultural land. Further, the soil map of the study area has been generated.



Concluding Remarks from Objective #b: Brahmani and Baitarani Basin have undergone major LULC changes. The dense forest has decreased up to 56% and the open forest has increased significantly up to 200%. Human interference can be seen clearly as the built-up area has increased substantially to 15%. Agricultural and barren lands have also experienced substantial changes of up to 150% and 50%, respectively.

Objective (c)

Flood forecasting plays a significant role in managing coastal flooding. In this study flood forecasting model is developed taking bias corrected Numerical weather prediction model forcings. The streamflow was simulated for using the SWAT model and a error forecasting sub-model was implemented to minimize the error. Streamflow forecast simulated by SWAT Pothole model is updated using an error correction model taking error time-series, i.e., $\varphi(t)$, $\varphi(t-1)$, ……, $\varphi(t-d)$ as input, which is obtained during the SWATP calibration phase; where $\varphi(t)$ is the simulated error between the observed (Q_{obs}) and SWATP estimated (Q_{sim}) discharge at any time, t, calculated as $\varphi(t) = Q_{obs}(t) - Q_{sim}(t)$. Where, d is the effectively correlated time lag obtained by auto-correlation function analysis of the error time series. The error-correction (forecasting) models are enlisted as: i) AutoRegressive (ARu); ii) AutoRegressive Moving Average with eXogenous inputs (ARMAXu), iii) Wavelet-based neural network (WNNu); iv) Dynamic wavelet-based Non-linear AutoRessive with eXogenous inputs (WNARXu)

Concluding Remarks from Objective #c: Using an error forecasting model to minimize the random error helped to improve the streamflow forecast at different lead-time. The NSE improved and falls in the range of 0.84 to 0.75 for a lead day of 1 to 5, respectively.

Objective (d)

Cyclones that make landfall on India's east coast are likely to cause inland floods and need real-time surge warnings to ensure minimum damage. The state-of-the-art numerical-wave models are often used for simulating such wind-driven events in the ocean. The work attempts to explore the effectiveness of a tightly coupled ADCIRC-SWAN model to compute water surface elevations as a combined effect of wind, astronomical tides, and waves. For the computation of storm tide, the coupled ADCIRC-SWAN model has been run for two simulations namely SIM1 and SIM2. The surge-wave model is calibrated for tropical Cyclone Fani (SIM1), which made its landfall on 3rd May 2019. Another Cyclone Yaas (SIM2), which hit the Bay of Bengal on 24th May 2021, is used to validate the model. As there are not many tide-gauge stations in the study region, the Dhamra tide gauge, located near the banks of Brahmani is considered for validation purposes. The computed water levels are compared with the measured tide gauge levels.

Concluding Remarks from Objective #d: The coupled model produced a Nash-Sutcliffe Efficiency (NSE) coefficient of 0.85 during the SIM1 run and 0.83 during the SIM2 run which shows good robustness of the tightly coupled model in predicting ocean water surface elevations i.e., tides and surges.

Objective (e)

#HEC-RAS 2D model simulation

The trials are initially carried out to map flood inundation in the BBD (Brahmani-Baitarani Delta) during the Yaas cyclone, which made landfall to the north of Dhamra port as a result of storm tide, upstream discharge, and precipitation. At BBD mouth, the ADCIRC-SWAN estimated temporal tide values serve as a downstream boundary condition. The HEC-RAS model has been set-up of BBD using Copernicus DEM with 30 metres resolution. The perimeter of the 2D flow area is defined along the boundary of the BBD. Computational points are generated with a grid spacing of 90 meters. The model based on 2D diffusive wave equation is run for the same period in which the ADCIRC-SWAN model has been executed. The results of the flood inundation simulation in BBD are presented in Figure 5.7.

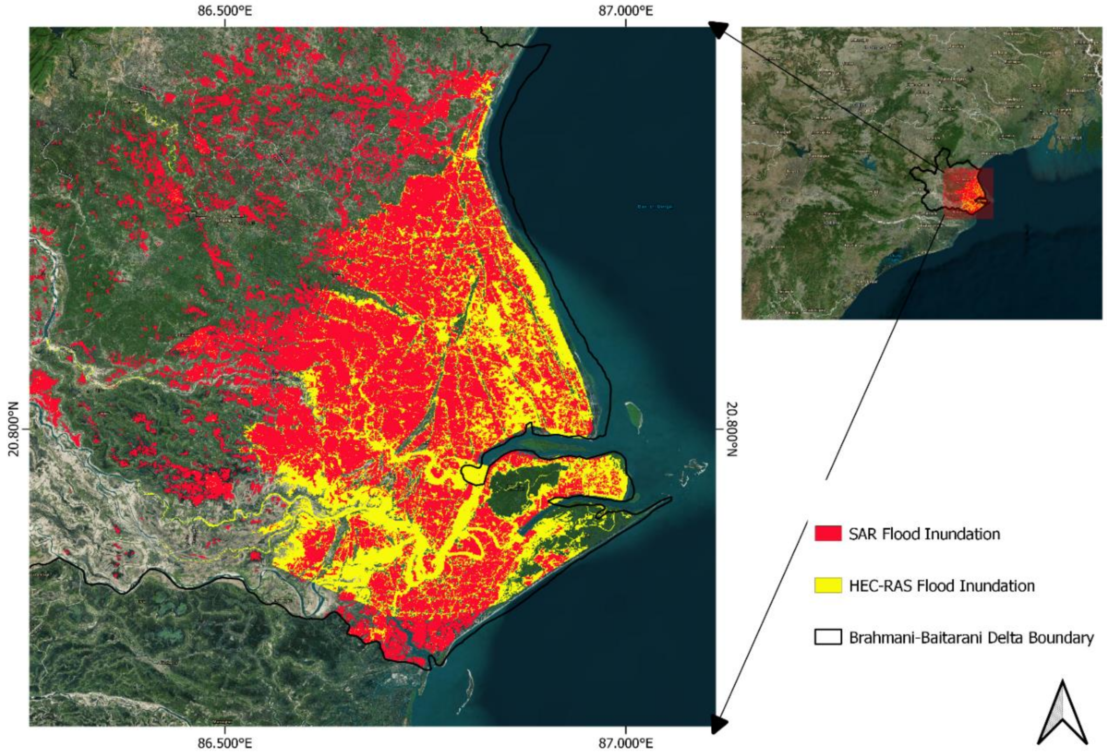


Figure 2. Flood inundation map of BBD generated based on HEC-RAS 2D simulation and SAR (Sentinel-1) extracted inundation extent.

Concluding Remarks from Objective #e: The flood inundation extent at BBD by HEC-RAS 2D model is shows an overall accuracy of 81.6% and Cohen's Kappa Coefficient of 0.63 as compared to those extracted from SAR satellite data.

Future Plan

- Simulation of real-time 2D flood inundation maps in the deltaic basin considering upstream streamflow forecasts with stream-aquifer exchange fluxes and downstream tidal/sea-surge forecasts up to 10-days lead-time:

- Development of flood vulnerability maps in real-time (up to 10-days advance) for operational flood management considering the guidelines of the UNESCO-IHE . The best combination of the models, adaptable to data-scarce situations, would be chosen through rigorous testing for developing the maps in real-time.

ONGOING STUDIES (INTERNAL)
2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

1. Title of the Project

Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Flood Management

2. Project Coordinator: Dr. A. K. Lohani, Sc-G (PI), NIH Roorkee
Dr. R. K. Jaiswal, Sc-E (PI), NIH, CIHRC, Bhopal

Project Investigator(s)

Dr. J.P. Patra, Sc-E (Co-PI)
Dr. P. C. Nayak, Sc-F (Co-PI)
Dr. Vishal Singh, Sc-D (Co-PI)

3. Objectives

- To analyse rainfall and runoff for selected reservoirs
- To carry out water balance of reservoirs for computation of runoff
- To develop rainfall-runoff model for the catchment of reservoirs
- To develop integrated framework for real time flood forecasting using cloud based climatic data for early warning and efficient flood management
- To develop hydrodynamic model for assessment of flood impact downstream of dam

4. Present state-of-art

Flooding is an overflowing of water onto land that is normally dry. floods can happen during heavy rains, when ocean waves come on shore, when snow melts too fast, or when dams or levees break. flooding may happen with only a few inches of water, or it may cover a house to the rooftop. Floods are catastrophic events that cause damage to lives and properties. Due to the impact of climate change, high intensity rainfalls are being observed in the most part of world and India. These extreme precipitations may cause unprecedented runoffs and resulting in higher floods in the catchment. The recent change in climate pattern and land use in the catchment further aggravate the situation especially downstream of dams and reservoirs. The old formulae used to compute routed flood and flood protection works need to be evaluated and reformulated under changing climate situations.

Generally, regression based equations are commonly used for flood forecasting at reservoirs. In this method, water levels in the upstream and future forecast conditions from IMD are used to determine inflow in the reservoirs and according operation of gates are made during flood season. Nowadays, several sources of forecast data for climate variables on grid levels are available which can be used in well calibrated rainfall-runoff model to determine possible inflows to the reservoir through an integrated system. The gathered knowledge of future inflows can be used for efficient reservoir operation and assessment of downstream flood and issue appropriate preparedness for evacuation in the event of high flood. In the present study, Tawa dam of Madhya Pradesh, Ravi Shankar Sagar dam from Chhattisgarh, Dharoi dam from Gujarat and Beesalpur dam from Rajasthan in India.

5. Methodology

Methodology for the automation of the forecasting model is presented in Figure-1. The GIS database of Tawa dam catchment consisting of topography, land use, soil, drainage, downstream structures etc. has been created. This GIS database works as base information for modeling the rainfall-runoff processes. Further a rainfall-runoff models has been developed to assess the production of water from catchment under given hydrological conditions. In the study, HEC-HMS rainfall-runoff model on a daily basis has been developed for Tawa reservoir catchments. Calibration and validation results of the model are presented in Figure 2,3 and 4. The developed model will be able to accommodate future forecast climate data for the forecast of runoff with acceptable accuracy.

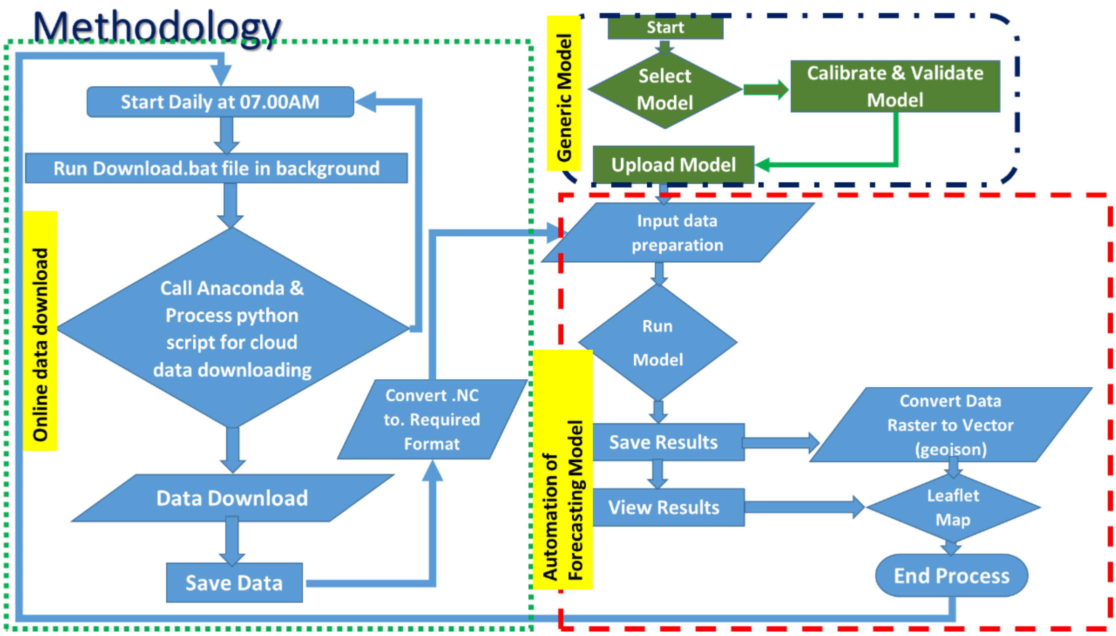


Figure-1: Methodology of Flood Forecasting System

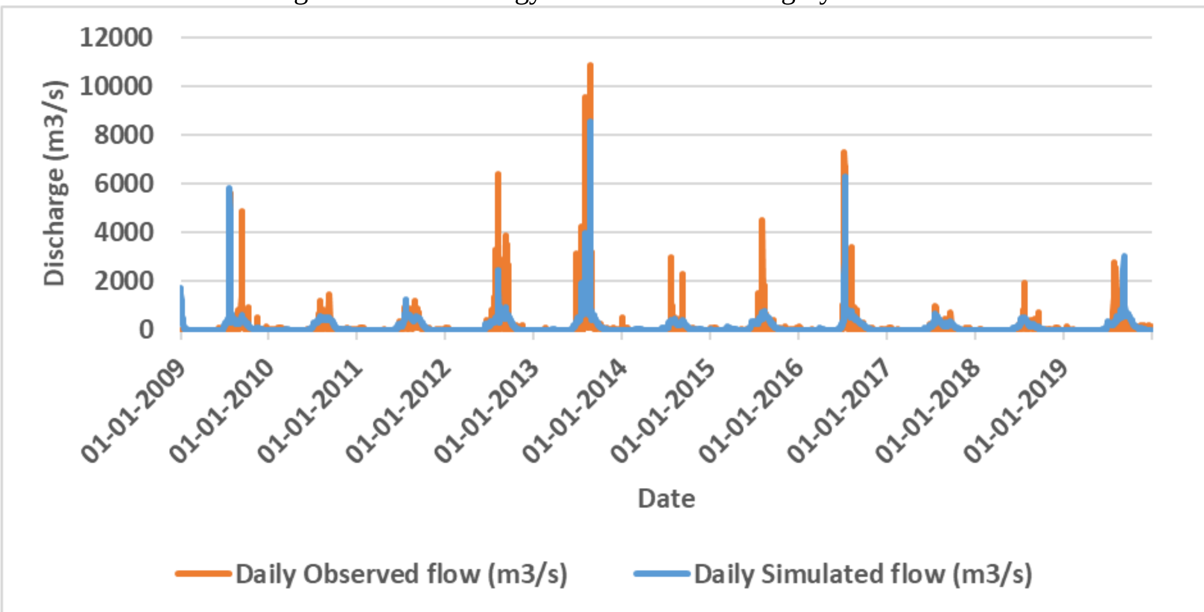


Figure-2: Calibration and validation of Tawa reservoir inflow

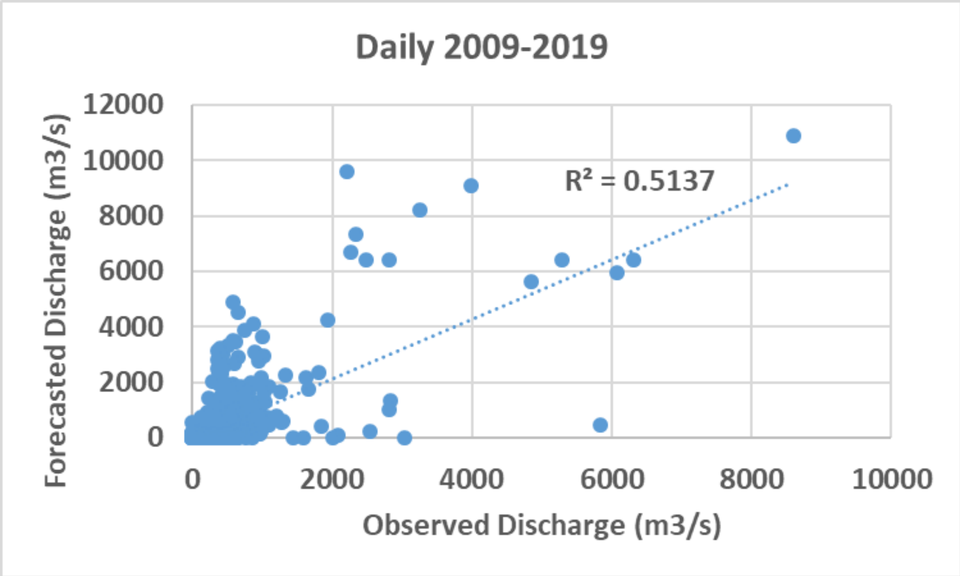


Figure-3: Scatter plot of observed and computed Tawa reservoir inflow (2009-2019)

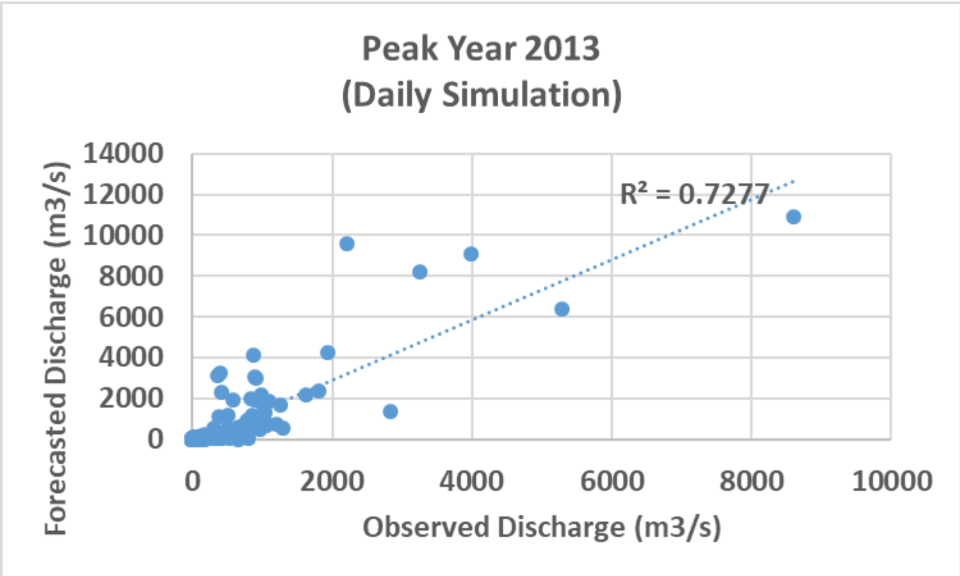


Figure-4: Scatter plot of observed and computed Tawa reservoir inflow (Peak flow 2013)

6. Research outcome from the project

The catastrophic events are more and more common in all over the world and India. The proposed integrated system for forecasting reservoir inflows will be useful to water resource Departments of respective states for efficient reservoir operation and issue emergency warning well in advance to evacuate the people. The general public will be benefitted by getting timely information in the event of catastrophic flood situation.

ONGOING STUDIES (INTERNAL)
3. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

Title of the Study: Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model

Study Group: PI :P. C. Nayak, A. K. Lohani, J. P. Patra, Sunil Gurrapu, T. Thomas, Om Prakash, Jatin Malhotra

Type of Study: Internal Study
Nature of Study: Basic and Applied Research
Date of Start: July 2022
Scheduled date of Completion: June 2025
Duration of the Study: 3 years

Study Objectives

- Develop a deep neural network-based hydrologic model to predict the long-lead-time flood forecasting
- Comparison between conceptual/distributed model with deep neural network to improve the flood forecasting
- The performance of the proposed model will be tested for Baitarani basin in Odisha state
- To predict the long leand time flood forecasting under changing climatic conditions, *i.e.,* include the GCM models output for future predictions

In the whole world one of the most common disasters is flood. Changing climatic conditions impact the river flow, which creates the flood conditions in all over the world. Flood often causes human loss, economic loss etc, so for that reason flood forecasting study is very important in today's scenario. Flood forecasting can help the water agencies to prepare advance disaster management map. Flood forecasting tools can be divided into conceptual models, physical models, and black box models. Here, flood forecasting technique is used for Baitarani basin of India. The Baitarani river rises in the hill ranges of Keonjghar district of Orissa at an elevation of about 900m and has length of about 355km. The Baitarani basin extends over 12,789 km^2 and is roughly circular in shape. The main tributaries of Baitarni joining from left are the Salandi and the Matai. Two gauge stations Anandpur and Champua are considered for analysis in the Baitarani basin using Long Short Term Memory (LSTM) technique. Latitude and longitude of Anandpur and Champua are 21^{o}12', 86^o 07' and 22^o 03' and 85^{o}39' respectively.

Artificial Neural Network (ANN) models offer great forecasting skills for predicting long-term hydrological variables. ANNs are the most widely used Machine Learning (ML) method due to their accuracy, high fault tolerance and powerful parallel processing in dealing with complex flood functions especially where datasets are not complete. The most successful and widely used Recurrent Neural Network (RNNs) is the Long Short Term Memory (LSTM) network. LSTM model has been calibrated and validated for two gauging sites namely Champua and Anandpur Rainfall, water level, and discharge data from 1991 to 2021 is used for flood forecasting in which 70% data used for training set and 30% is used for testing set. 0.25 daily gridded rainfall data is downloaded from IMD website and water level, discharge data is provided by CWC, India for about 30years (1991-2021).
Table1 summarizes the performance indices for both of the gauging sites with the 1 day and 2day lead time. Flow Duration Curve is shown in Fig1 and 2 for the calibration of Anandpur and Champua site with 1day lead time.

Table1: Performance indices

Gauging site performance indices		Champua (1-day)	Champua (2-day)	Anandpur (1-day)	Anandpur (2-day)
Correlation	Calibration	0.97	0.94	0.96	0.96

	Validation	0.95	0.91	0.05	0.94
Efficiency	Calibration	90.30	75.14	88.94	83.61
	Validation	87.14	60.08	88.92	80.89
RMSE	Calibration	20.29	25.22	130.09	158.40
	Validation	25.67	32.59	118.38	155.52
R^2	Calibration	0.95	0.94	0.95	0.96
	Validation	0.96	0.95	0.96	0.95

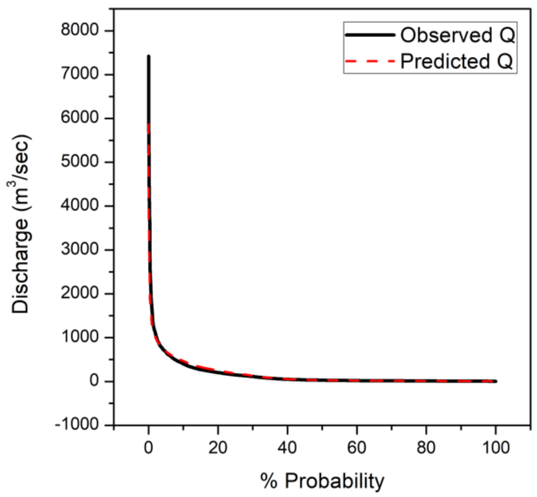


Fig1: Flow Duration Curve at Anandpur

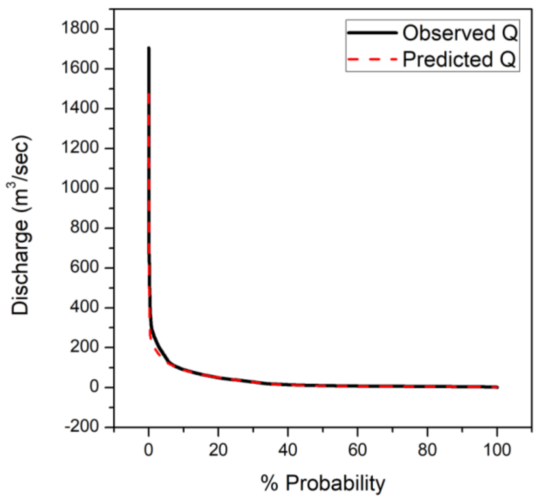


Fig2: Flow Duration Curve at Champua

Objective vis-a-vis Achievement

As mentioned in the objectives, preliminary investigation has been conducted to forecast flood for Champua and Anandpur gauging site for 1day and 2 day lead.

Progress since last meeting

The required hydrological has been collected from Odisha Water Resources Department and CWC, Bhubaneswar. Analysis is under progress

Future work for the next year: Flood forecasting using conceptual/physics based model is under progress

ONGOING STUDIES (INTERNAL)
3. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

1. **Title of the Project**: Hydrological Study for revival and restoration of traditional water bodies in Bikaner, Rajasthan

2. **Project team:**

a. Project Coordinator	Dr. A. K. Lohni, SC-G
b. PI Project Investigator(s)	Dr. L. N. Thakural, Sc-D, Lead PI Dr. M. K. Shama,Sc-E Dr. Rahul Kumar Jaiswal, Sc-E Sh. J. P. Patra, Sc-D Dr. P. K. Mishra, Dc-D Dr. Nitesh Patidaar, Sc-B Sh. N. K. Bhatnagar, Sc-B, Sh. Jatin Malhotra, SRA,
c. PI from Partner Organisation:	Dr. Anil Kumar Chhangani, Professor Department of Environmental Science, Maharaja Ganga Singh University, Bikaner

3. **Present state-of-art**

Small traditional waterbodies including ponds and tanks are the most important water sources especially in rural areas. These waterbodies are increasingly recognized for their role in meeting rural water needs, aquifer recharge, providing livelihood opportunity, maintaining ecological balance and ecosystem services (Biggs et al., 2016). Small waterbodies are playing vital role in socio-cultural, economic and environmental development. Often, tanks and ponds support rural livelihoods of the marginalized community in rural, urban, coastal and tribal areas. There are about 5,00,000 tanks in India and mostly situated in semi-arid parts of India. As per 5th Census of Minor Irrigation Schemes Report, in surface flow schemes, tanks/ ponds have largest share of 41% followed by reservoir (14%) and temporary diversions (10%). These tanks help in capturing the runoff during monsoon and providing water for irrigation and other multiple uses for the community. However, continued unsustainable exploitation, increasing negligence and lack of conservation and urban growth resulting in huge adverse impact on these small waterbodies. In the last few decades, waterbodies have been under continuous and unrelenting stress, caused primarily by rapid urbanisation and unplanned growth. Encroachment of these waterbodies, often, identified as one of the causes of urban floods. Further, these waterbodies are being polluted by untreated effluents and sewage (Bindu and Mohamed (2016); Matto, 2019). Waterbodies are the lifeline for human existence and always the backbone of water resource sustainability in any urban area. They are going to disappear around the world. Solid waste dumping, industrial pollution, sewage pollution, encroachments, commercial fish farming and other practices are the main causes of this situation. Urbanization and industrialization have increased the intensity of pollution to such an extent that waterbodies' self-healing capacities are no longer enough to counter these multiple onslaughts. Flood mitigation, groundwater recharge, biodiversity enhancement, industrial development and water security are just a few of the benefits that waterbodies provide to a city. It is time their role is properly evaluated in the urban economy and effective actions are initiated for their rejuvenation. Bikaner city has a number of water bodies since ancient time, which has been disappeared due to ignorance and non-maintenance of these water bodies.Bikaner city will be studied followed by broad recommendations on site-specific approaches for revival and restoration.

4. Objectives:

a) To prepare inventory of water bodies in Bikaner and to understand the role of the water bodies in the human survival, livestock and livelihood sustainable and in biodiversity conservation.
b) Long-term spatio-temporal analysis of rainfall, temperature and meteorological variables.
c) Landuse land cover (LULC) change detection in the study area and selection of pilot water bodies (ponds).
d) Trend analysis of groundwater levels and assessment of recharge to groundwater in Bikaner district
e) Surface water availability analysis of pilot water bodies.
f) Identification of various issues both quantitative and water quality assessment of pilot water bodies.
g) To understand the socio-economical role of the water bodies to meet the daily requirement of community for water and other natural resources in and around water body.
h) To understand the existing governance and management practices of water bodies by the local community or any other authorities.
i) Suggesting ameliorative measures to restore water quality of water bodies and daptive and mitigation measures for rejuvenation and sustenance of water bodies.

5. Present state-of-art

Small traditional waterbodies including ponds and tanks are the most important water sources especially in rural areas. These waterbodies are increasingly recognized for their role in meeting rural water needs, aquifer recharge, providing livelihood opportunity, maintaining ecological balance and ecosystem services (Biggs et al., 2016). Small waterbodies are playing vital role in socio-cultural, economic and environmental development. Often, tanks and ponds support rural livelihoods of the marginalized community in rural, urban, coastal and tribal areas. There are about 5,00,000 tanks in India and mostly situated in semi-arid parts of India. As per 5th Census of Minor Irrigation Schemes Report, in surface flow schemes, tanks/ ponds have largest share of 41% followed by reservoir (14%) and temporary diversions (10%). These tanks help in capturing the runoff during monsoon and providing water for irrigation and other multiple uses for the community. However, continued unsustainable exploitation, increasing negligence and lack of conservation and urban growth resulting in huge adverse impact on these small waterbodies. In the last few decades, waterbodies have been under continuous and unrelenting stress, caused primarily by rapid urbanisation and unplanned growth. Encroachment of these waterbodies, often, identified as one of the causes of urban floods. Further, these waterbodies are being polluted by untreated effluents and sewage (Bindu and Mohamed (2016); Matto, 2019). Waterbodies are the lifeline for human existence and always the backbone of water resource sustainability in any urban area. They are going to disappear around the world. Solid waste dumping, industrial pollution, sewage pollution, encroachments, commercial fish farming and other practices are the main causes of this situation. Urbanization and industrialization have increased the intensity of pollution to such an extent that waterbodies' self-healing capacities are no longer enough to counter these multiple onslaughts. Flood mitigation, groundwater recharge, biodiversity enhancement, industrial development and water security are just a few of the benefits that waterbodies provide to a city. It is time their role is properly evaluated in the urban economy and effective actions are initiated for their rejuvenation. Bikaner city has a number of water bodies since ancient time, which has been disappeared due to ignorance and non-maintenance of these water bodies. Bikaner city will be studied followed by broad recommendations on site-specific approaches for revival and restoration.

6. Methodology:

- Present GW Scenario and trend analysis
- Estimation of GW recharge
- Trend analysis using statistical approach

- Assessment of Land use/Land Cover and its impact on runoff characteristics in the catchments of Waterbodies
- Assessment of Soil Loss from the catchments
- Surface water availability analysis
- Water Quality Assessment from water bodies
- Site-specific approaches for revival and restoration
- True repositories of biodiversity

7. Research outcome from the project:

The outcome of the study will help in the revival and restoration of ponds in Bikaner. bodies.

8. Progress:

The water bodies in Bikaner were identified and mapped. The catchment area of selected water bodies located in both urban and rural areas has been delineated using a digital elevation model (Cartosat DEM) with a spatial resolution of 30 m in the GIS environment. The Lanuse/Landcover for the study area has also been prepared using Landsat 8 imagery for the year 2020. The daily gridded IMD data of rainfall (0.25°x0.25°), maximum temperature, and minimum temperature (1°x1°) for the period 1951-2020 were downloaded. The daily data were processed and converted to a monthly scale. Homogeneity Tests for rainfall, maximum temperature, and minimum temperature series were performed to detect the change point using four widely used tests namely the Pettitt test, standard normal homogeneity test (SNHT), Buishand range test, and von Neumann ratio test on an annual and seasonal time scale. Moreover, non-parametric approaches (Mann Kendall and Sen slope of Estimator) were employed to detect and quantify trends in these variables. A reconnaissance survey and collection of water samples of the 15 water bodies including the water bodies referred by the Ministry of Jal Shakti has been carried out during the field visit of Bikaner. Some parameters like pH and electrical conductance were measured on the spot by means of portable meters (HACH, USA). For other parameters, samples were preserved by adding an appropriate reagent and brought to the laboratory in sampling kits maintained at 4°C for detailed chemical analysis. The analysis of physico-chemical parameters DO, BOD, COD was performed as per standard methods (APHA, 2017). Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4) were analyzed using Ion Chromatograph. Ionic balance was calculated, the error in the ionic balance for majority of the samples was within 5%. The location map of the sampling sites is shown in Fig.1

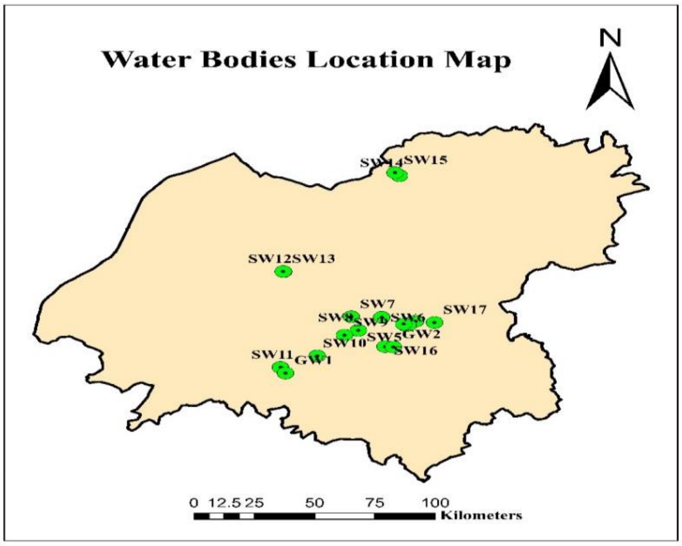


Fig. 1. Map showing locations of sampling sites

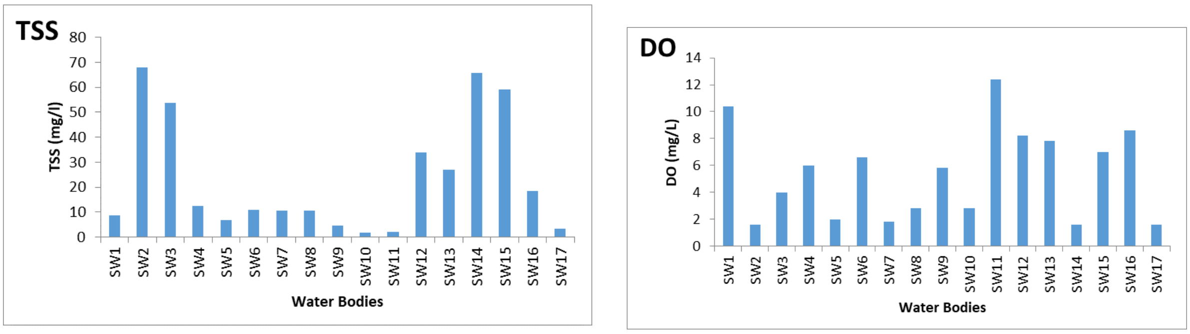
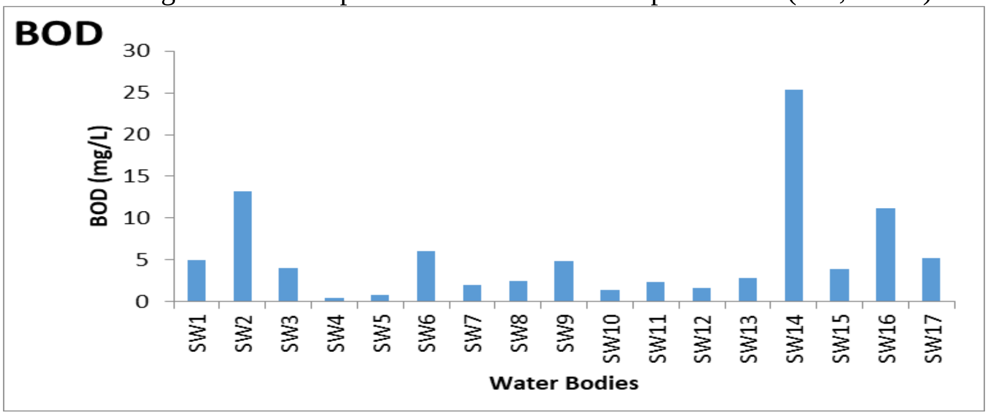


Fig 2: water samples for TSS and Demand parameters (DO, BOD)



Soil investigation was performed in the urban and rural areas of the Bikaner district. Soil samples from seven different locations were collected and analyzed in the Soil Water Lab of NIH for deriving soil texture and soil moisture characteristic curves. It was observed that the texture is mainly sandy in the area with more than 50% sand proportion at all locations. An infiltration test was performed in the field using a double ring infiltrometer at four locations. The infiltration rate varies approximately from 16 to 20 mm/hr in the study area. The groundwater status and trends were also carried out for the detection of trends in groundwater level utilizing groundwater level data acquired from CGWB. The results reveal that a rising trend (in 43% wells) is observed towards the IGNP canal, while the groundwater is falling in the Southern parts (in 21% wells) and approximately 35% of wells show a no-trend in groundwater levels of the Bikaner district for the period 2001-2020.

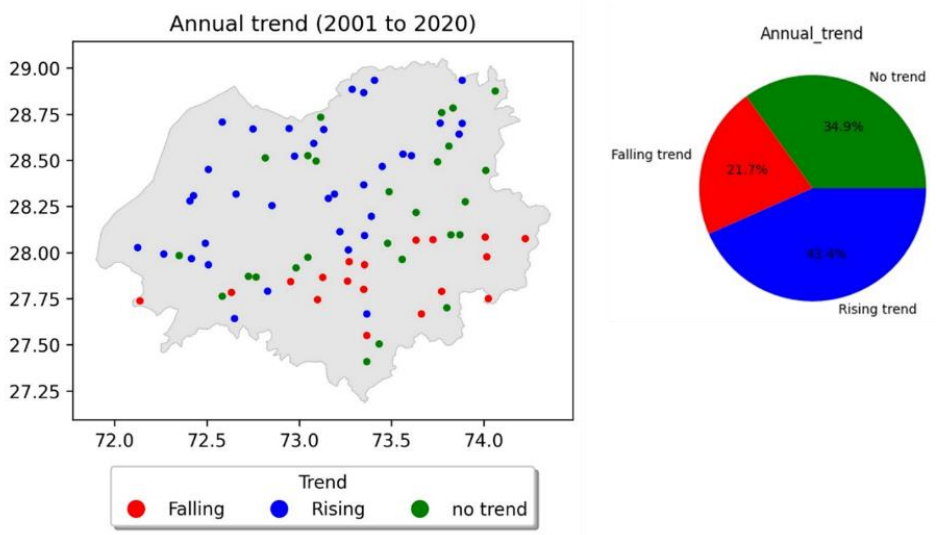


Fig. 3. Trend in groundwater levels in the Bikaner district

ONGOING STUDIES (INTERNAL)

4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-25

1. Title of the Project

Review of design flood and dam break analysis of Khadakhai Dam in Odisha.

2. Project team:

a. Project Investigator:	J.P.Patra, Sc. – D, SWHD
b. Project Co-Investigator:	A. K. Lohani, Sc. – G & Head SWHD
	Pankaj Mani, Sc. – F, CFMS Patna
	P. C. Nayak, Sc. – F, SWHD
	Sanjay Kumar, Sc. – F, SWHD
	Jatin Malhotra, SRA
c. WRD Odisha:	Tapas Pattanaik, Damsaftey
	Tareni Sen Dhala, CE & BM Subarnarekha

3. Duration of the Study: 3 years (April 2022 to March 2025) : Ongoing

4. Type of Study: Internal Study

5. Location Map

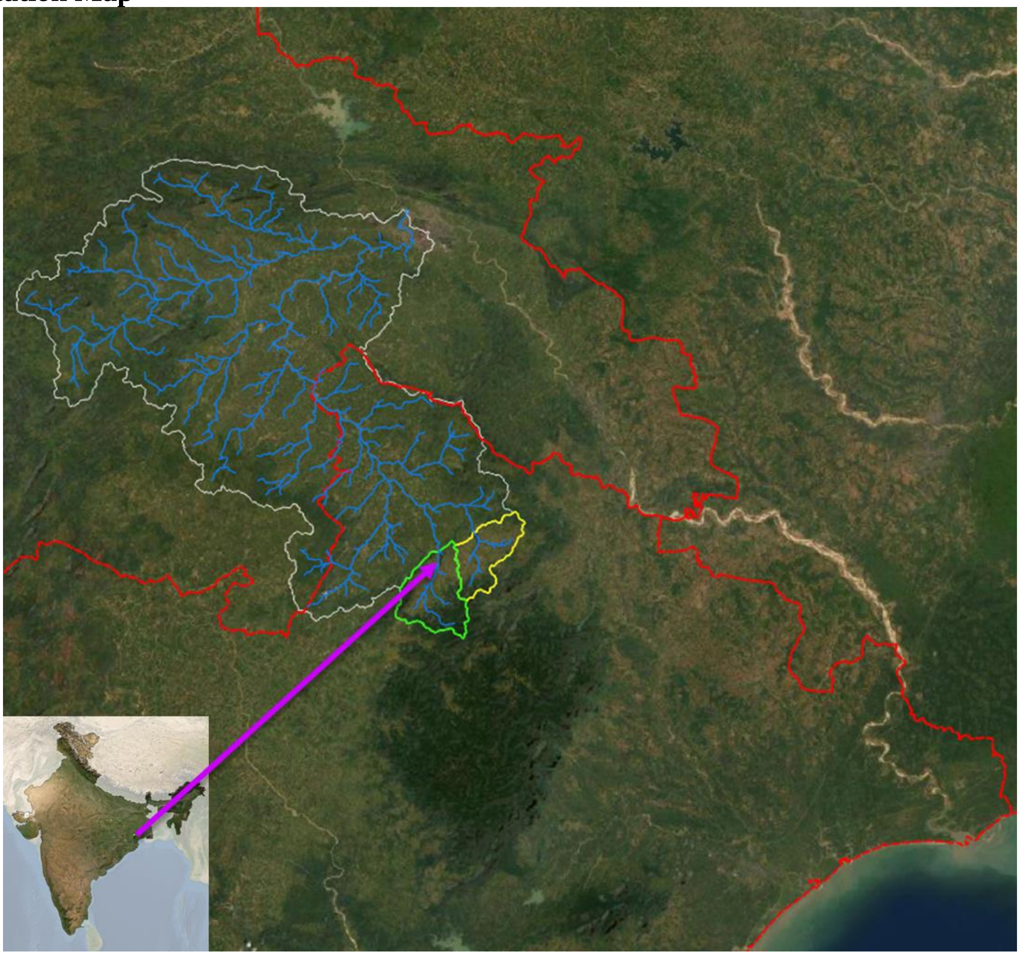


Figure 1: Location map of the study area

6. Objectives

a. To estimate design flood for the Khadakhai Dam.
b. To analyses uncertainty associated with estimation of design floods in view of future climate projections.
c. To review and improvement of Khadakhai Dam operation rule curve.

d. To prepare dam breach flood inundation maps for various scenarios.
e. To access sensitivity of the flood inundation maps due to uncertainty in estimate of design flood, breach parameters and reservoir sedimentation.

7. Statement of the problem

The Khadakhai Dam is an earthen dam of 365.4 m length build across Khadakhai river in 1981. The maximum height above foundation of the dam is 37 m. It has been constructed on two ends of hills i.e., Bhitarmda hill and Karanjharan hill end points. The reservoir is known as Suleipat reservoir, created mainly for irrigation purpose. In April 2012, Ministry of Water Resources, River Development & Ganga Rejuvenation through Central Water Commission with an objective to improve safety and operational performance of selected dams started the Dam Rehabilitation and Improvement Project (DRIP) with World Bank assistance. Design flood review and preparation of EAP are two important activity in DRIP. The older dams are designed with limited data and atmospheric realities of that period. Now, as those realities shift dramatically with the climate crisis, and need to be relooked. A dam operator has to manage the water release and storage cycle in such a manner that at the end of the monsoon period, its reservoir is at its full capacity. The storage and release schedule of a dam is governed by a rule curve. However, these rule curves are based on monsoon patterns of a time when such patterns were far more predictable, and less disrupted by climate change than they are today. Dam breach modelling is a key component to a well-rounded and robust dam safety program. Various researcher and guidelines recommended combination of breach parameters. The parameters are highly sensitive to peak flood and resulting flood inundation extent. This is further increased with uncertainty in design flood, reservoir operation policy, reservoir sedimentation etc. These needs to be addressed systematically while developing flood inundation map and EAP.

8. Approved action plan and timeline

S.N.	Work Element	1st Year	2nd Year	3rd Year
1	Collection of basic data, topography, cross-section, satellite images, thematic maps etc.			
2	HEC-HMS model setup, review & estimate design flood			
3	Uncertainty analysis for design floods with future climate projections.			
4	Analysis of operation rule curve			
5	HEC RAS model setup for dam beach modelling			
6	Dam breach flood inundation modelling and combined general flood hazard classification			
7	Review and analysis of reservoir sedimentation and updating of EAC table			
8	Sensitivity of the flood inundation maps.			
9	Workshop/ Training.			
10	Report.			

9. Brief Methodology

It is proposed to develop a rainfall runoff model using HEC-HMS for estimating design flood hydrographs at the dam site. Design flood will be estimated using the recently developed PMP atlas. Further, the future climate projections (INCC), non-stationarity in the rainfall/ discharge pattern along with LULC changes will be analysed for assessing uncertainty in the design flood estimates. Based on the estimates of design flood it is proposed to evaluate and improve the existing rule curve in DSS (PM) platform. The dam break analysis will be carried out using HEC RAS. Sensitivity analysis will performed to access sensitivity of the flood inundation maps due to uncertainty in uncertainty in design flood, reservoir operation policy, reservoir sedimentation etc.

10. Results achieved with progress/present status

The salient features of Khadakhai dam is obtained from the project authority and literatures. The physiographic parameters of the river catchment at dam site have been estimated by GIS processing of STRM DEM. The catchment area map of the project comprising of elevation band, drainage/ catchment area at dam site is shown in Figure 2. The Synthetic Unit Hydrograph is developed using these catchment characteristics and relationships provided in flood estimation report for Lower ganga plains subzone-1g (CWC, 1994). The manual on estimation of design flood analysed time distribution pattern of storms in the area for which adequate self-recoding rain-gauge data are available. In the manual, depth duration analyses of maximum rainfall depths for standard duration of 6, 12, 18, 24, 36, 48 hours etc., were obtained for each of the storms and expressed as percentage of the total storm depth. Enveloping percentages are then obtained and applied to adjust the design rainfall based on observational data. In absence of hourly rainfall data it is recommended to apply a factor of 1.15 to convert 1-day maximum rainfall to 24-h maximum rainfall. The 24 hour rainfall is divided in to incremental hourly rainfall according to time distribution provided in the CWC report. To obtain the critical sequence of rainfall the largest of increments is placed against the peak of UH, then the next largest against the next UH ordinate and so on until all rainfall increments get arranged. Then the sequence is reversed to get the critical sequence for all spells. In case of 24-h duration rainfall the first and second 12 h blocks are interchanged to get critical situation. The design loss rate is subtracted from the hourly rainfall to obtain effective rainfall hyetograph and then direct runoff hydrograph is estimated by convoluting this effective rainfall with SUH. Finally, the base flow is added to obtain design flood hydrograph. The HEC HMS model has also been prepared with IMD gridded rainfall data as input. The HEC RAS model for Dam break modelling is being prepared.

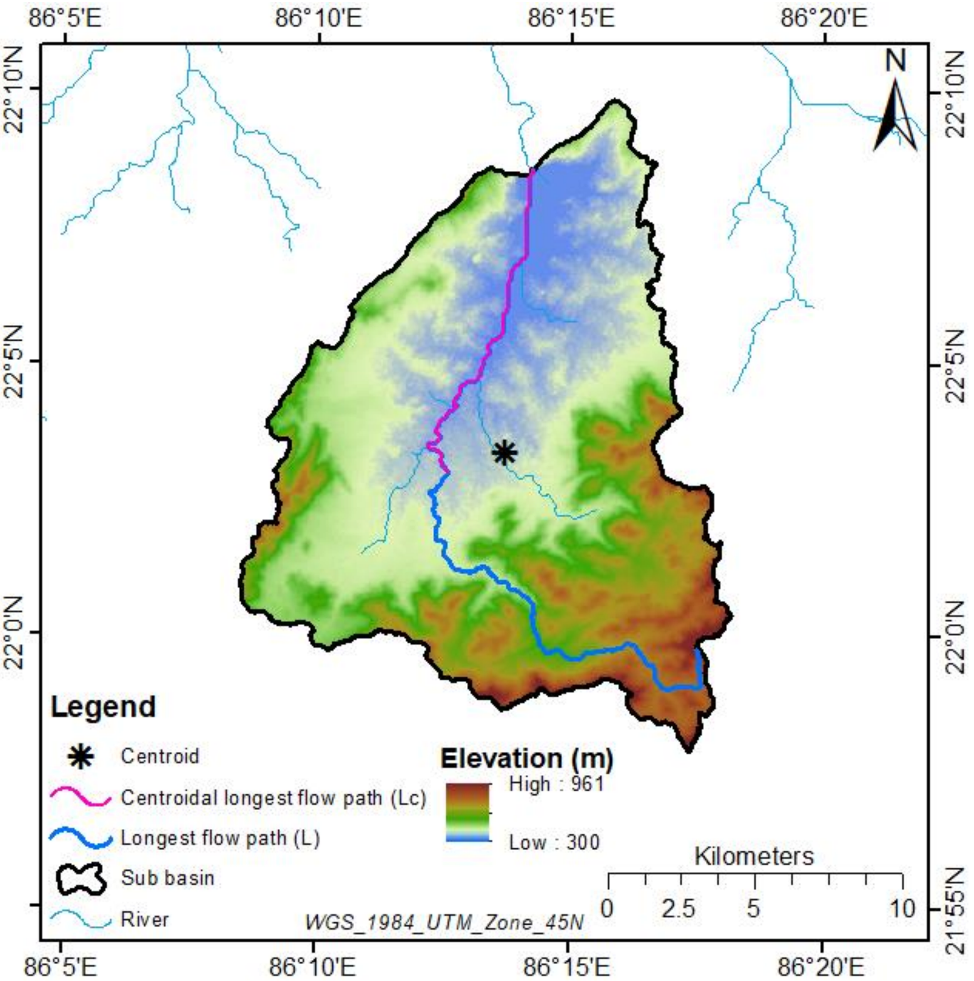


Figure 2: Catchment area map for Khadakhai dam.

11. Research outcome of the project

- Revised design flood for the Khadakhai Dam.
- Flood inundation maps along with depth, velocity, time of flood arrival, combined flood hazard due to large controlled release and dam break of Khadakhai Dam.
- Capacity building in line with DRIP.
- Application of DSS (PM) developed under NHP

12. End Users/Beneficiaries of the study:

Department of Water Resources, Govt. of Odisha

ONGOING STUDIES (INTERNAL)
7. PROJECT REFERENCE CODE: NIH/SWD/NIH/21-24

Title of the Project:	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin
Project Team:	Dr. R. V. Kale, Sc. D, SWHD, NIH Roorkee (PI) Er. D. Khurana, SRA, WHRC NIH Jammu (Co-PI)
Collaborating agency	
Type of Study	Internal Project (NIH)
Duration	3 years
Date of Start	September 2021
Date of Completion	October 2024
Budget	Rs. 90,000/-

Statement of Problem

The water-related disasters particularly flood hazard is on rise all over the world particularly in the western Himalayan region in its frequency, magnitude and damage caused to property and society. Therefore, there is very high societal demand to cope with flood hazards and incurred damages. Usually, in conditions of scarce data availability, a preliminary and cost-effective floodplain delineation can be carried out using procedures that relay on the analysis of geomorphic features (Manfreda et al., 2014). The worldwide conducted studies have shown that geomorphic behaviour and form of rivers across the world have changed strongly compared to a century ago due to land cover change and/or infrastructure construction (Schwenk et al., 2017). These changes to river planform and geomorphic dynamics have caused, and continue to cause, ecological, hydrological and environmental impacts. These river changes can be attributed to processes occurring over multiple timescales. As observed changes in geomorphic dynamics in rivers are strongly timescale-dependent, limiting a geomorphic study to a single timescale can cause biased observations in channel dynamics, with long-term measurements leading to underestimations of the total change occurring over shorter timescales (Harvey and Gooseff, 2015; Donovan and Belmont, 2019). With recent technological advancements, access to Google Earth Engine (GEE), a cloud-based computing platform for planetary-scale geospatial analyses offers access to petabytes worth of remotely sensed Earth observation data (e.g., multi-spectral satellite imagery) (Gorelick et al., 2017), enabling meaningful geomorphological analyses at higher spatial resolutions, over greater spatial extents and at finer temporal resolutions than ever before. Relevant to flood risk management, recent applications of GEE include the integration of Synthetic Aperture Radar (SAR) imagery with optical satellite imagery (e.g., Landsat collections) for event scale flood detection and monitoring (e.g., DeVries et al., 2020).

A considerable number of studies have demonstrated the use of the one- and two-dimensional (1D and 2D) numerical models to delineate floodplains, which allow an accurate representation of river hydraulics and floodplain inundation dynamics. Simplified 2D models have a solid advantage by being computationally significantly more efficient than, for instance, fully 2D models based on the complete St Venant equation (Néelz and Pender 2013). Previous research study by Néelz and Pender (2013) clearly indicates that for the representation of flood extent all 2D packages perform comparably (those which solve full shallow water equations and those, which neglect/simplify certain terms). For the data-scarce areas and flashy river basin, hydrological and inundation models play a critical role on flood simulations, planning of an emergency flood disaster risk management activity, planning of long-term flood control counter measures and risk assessment (Chao et al., 2019, Yu et al., 2018).

Taking into account all the issue discussed in above section, the present study likely to attempt to utilize power of a cloud-based GEE to analyses the planforms changes. Further, this study attempts to evaluate the predictive capabilities of two-dimensional Rainfall-Runoff-Inundation (RRI) model and its comparison with HEC-RAS/HEC-HMS model results in development of flood inundation mapping.

Objectives

a) To use a cloud-based Google Earth Engine (GEE) computing platform to systematically identify inter-annual changes in river planform morphology
b) Interpret changes in channel conveyance that are relevant for flood risk assessment
c) To evaluate predictive capabilities of Rainfall-Runoff-Inundation (RRI) model in development of flood inundation map
d) To carry out comparison of the RRI model-based flood inundation maps with those obtained by using HEC-RAS and HEC-HMS models.

Brief Methodology

The methodology followed to achieve the objectives of the study is briefly presented as follows:

a) To investigate spatial differences in river planform, the rivers will be classified into number of reaches defined by their physiographic setting and valley gradient
b) Google Earth Engine will be used to extract information on river planform morphology from multitemporal, multi-spectral satellite imagery. Landsat surface reflectance products (Landsat 5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper and Landsat 8 Operational Land Imager) and sentinel data products (Sentinel-1 SAR GRD and Sentinel-2 MSI) will be used as the primary source of satellite imagery available from 1988 onwards and other imagery data may be used in the investigation.
c) Various indices particularly Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI) and or Automated Water Extraction Index (AWEI) and other suitable approaches will be used to achieve active channel mapping at multi-temporal scale.
d) Numerous automated and semiautomated tools in python or MATLAB programming languages for planform analysis exist, with the outputs from GEE ready to be used to derive planform statistics and quantify change. These tools will be used to derive planform statistics and quantify the changes.
e) The Rainfall-Runoff-Inundation (RRI), a two-dimensional coupled hydrological and inundation model, which include three key components: a rainfall-runoff model, a river routing model, and a flood inundation model will be used develop the flood inundation map for the selected high flood events in the study as well as for 10-, 50- and 100-year return year flood at gauging site based on standard frequency analysis and unit hydrograph techniques.
f) Further, the flood inundation results for the study area by RRI model will be compared with those obtained by the application of the HEC-RAS and HEC-HMS model.

Study area

The River Tawi, which passes through the heart of the Jammu city, is an important tributary of the Chenab River in the Western Himalayan region. Tawi river originates from the lap of Kailash Kund glacier and adjoining area southwest of Bhadarwah in Doda district of the Union Territory of Jammu and Kashmir, India. The catchment area of the Tawi river basin is bounded by latitude 32° 35' 20"-33° 6' 6" N and longitude 74° 29' 8"-75° 40' 54" E which varies between 239 and 4331 m. The total catchment area up to its confluence with the Chenab river is around 2964 km. The basin shape in the upper part is elongated while broad in the lower part. The catchment of Tawi river up to Indian border is about 2745 km^2 falls mostly within the districts of Jammu and Udhampur of J&K state. Location of the Tawi catchment is shown in Fig. 1. The average height of the catchment is about 2200 m above mean sea level (msl). Being a mountainous river Tawi has more than 2000 numbers of tributaries and sub-tributaries. However, there are nine numbers of predominant tributaries of the river Tawi. The Tawi River is comprised of streams of 1-6 orders.

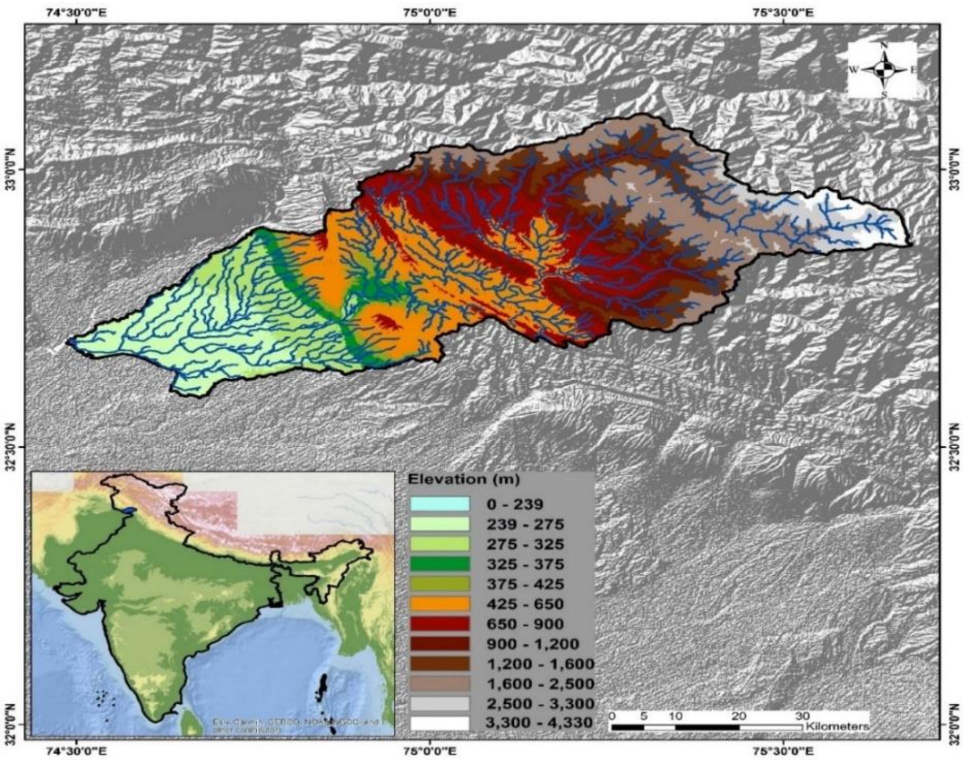


Figure – 1: Location map of Tawi river basin.

Action Plan

Stages of work and milestone:

Work Element	1st Year				2nd year				3rd year			
	1	2	3	4	1	2	3	4	1	2	3	4
Literature Review and detailed formulation of research approach												
Procurement/Collection of available hydro-meteorological data, river cross-section, gauge/discharge data, rating curve, satellite images, thematic maps. Collection of GCP and flood water mark data through field work (if condition permits) etc												
Development of codes in GEE												
Analysis of fluvial geomorphometric Planform results												
RRI model set-up for study area												
Comparison with HEC-RAS/HEC-HMS model results												
Results analysis												
Assessment of flood inundation under current and future changing climate												
Report writing	1st interim report				2nd interim report				Final report			

Achievements vis-à-vis Objectives

Objectives	Achievements
To use a cloud-based Google Earth Engine (GEE) computing platform to systematically identify inter-annual changes in river planform morphology	In-Progress
Interpret changes in channel conveyance that are relevant for flood risk assessment	In-Progress
To evaluate predictive capabilities of Rainfall-Runoff-Inundation (RRI) model in development of flood inundation map	In-Progress
To carry out comparison of the RRI model-based flood inundation maps with those obtained by using HEC-RAS and HEC-HMS models.	In-Progress

Progress of work

Objective (a)

Literature Review and detailed formulation of research approach

A through literature of the review has been carried out to formulate the research approach in the present study. These changes to river planform and geomorphic dynamics have caused, and continue to cause, ecological, hydrological and environmental impacts. These river changes can be attributed to processes occurring over multiple timescales. As observed changes in geomorphic dynamics in rivers are strongly timescale-dependent, limiting a geomorphic study to a single timescale can cause biased observations in channel dynamics, with long-term measurements leading to underestimations of the total change occurring over shorter timescales (Harvey and Gooseff, 2015; Donovan and Belmont, 2019). The changes in the Tawi planform during 1988 to 2022 based on the composite Landsat data is shown in Figure 2. It has been observed that significant changes in the planform of the Tawi river has been observed in the lower reaches downstream of the Sidhara gauging site as observed from following Figure 2. The further work is under progress to extract the planforms for various time scale from sentinel-1 and sentinel-2 images using proposed water masking filters.

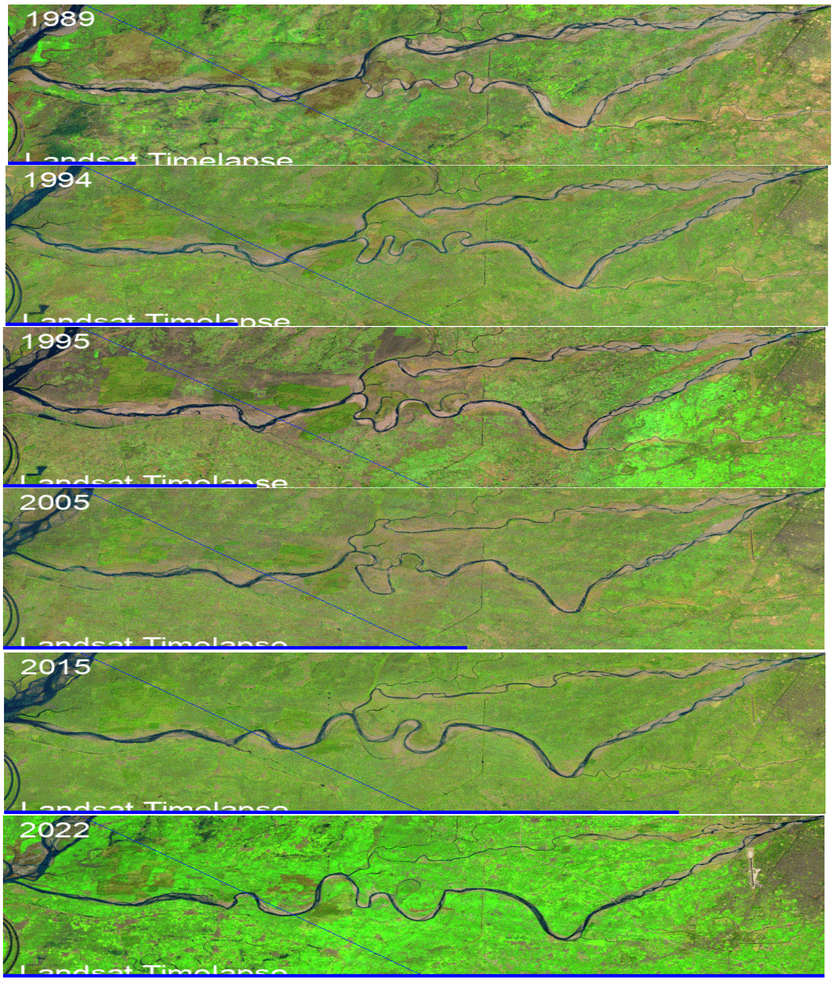


Figure 2: Observed changes in the Lower Tawi river planform during 1988 to 2022.

Most of the required available hydro-meteorological data, river cross-section, gauge/discharge data, rating curve, satellite images, thematic maps are collected.

The programming codes in GEE required to be improved and tested to achieve the results.
Objective (b)

Extracting the active river channel within Google Earth Engine (GEE): The programming code within Google Earth Engine (GEE) was used extract active river channel masks from Landsat 5, 7 and 8 satellite imagery. Three main processing steps: (i) cloud masking and temporal compositing; (ii) active river channel classification; and, (iii) cleaning and image export. The preliminary results achieved are shown in Figure 3. Similarly, the active river channel masks for various time-scales will be extracted for period 1988-2023.

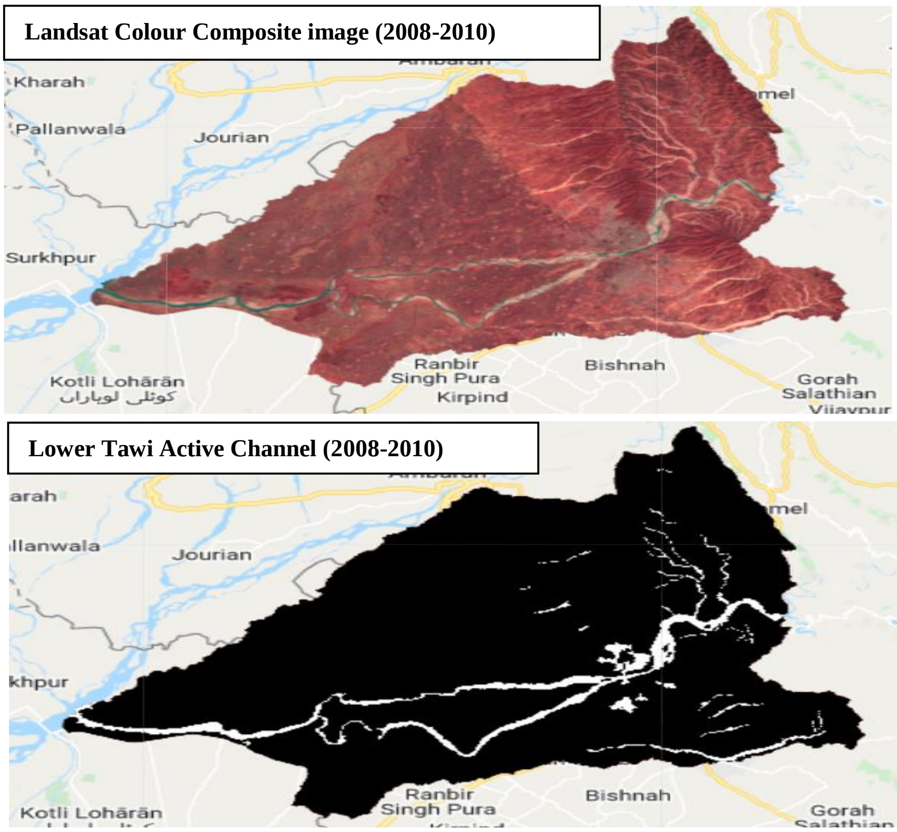


Figure 3. Extracted active lower Tawi river channel mask from a series of Landsat satellite images in Google Earth Engine

Objective (c)

The setting up the 2D Rainfall Runoff Inundation model is under progress. The primary results will be discussed in the working group meeting.

Future Plan

- Further development of codes in GEE to accomplish objectives (a) and (b)
- Analysis of fluvial geomorphometric Planform results
- RRI model set-up and calibration and validation for study area
- Writing up of interim report

NEW STUDIES (INTERNAL)
1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/23-25

1. **Title of Study:** Estimation of confidence intervals of index flow duration curves

2. **Study Group:** Sanjay Kumar, Sc-F, PI
Sunil Gurrapu, Sc-D, Co-PI
L. N. Thakural, Sc D, Co-PI
J. P Patra, Sc 'D' Co-P

3. **Study Period:** **Two Years (**April 2023 to March 2025)

4. **Objectives of the Study:** The objectives of the study are:
   - To develop Annual Flow Duration Curves (AFDC) and index flow duration curve.
   - To estimate the confidence intervals (90%, 95% & 99%) of index flow duration curves.

5. Statement of the Problem:
A flow duration curve (FDC) illustrates the relationship between magnitude and frequency of daily, weekly, monthly (or some other time period) streamflow, providing an estimate of the percentage of time a given streamflow was equaled or exceeded. FDC provides a graphical view of overall historical variability associated with stream flow in a river and thus have been used to solve problems in water resources engineering such as hydropower planning, water quality management, flood control, river and reservoir sedimentation etc.

An FDC is the complement of the cumulative distribution function (cdf) of daily streamflow and their interpretation depends on the particular period of records on which they are based. However, if one considers N individual FDCs, each corresponding to one of the individual N years of record, then one may treat those N annual FDCs in the same way as one treats a series of annual maximum and annual minimum stream flows. This annual based interpretation enables confidence intervals and recurrence intervals to be associated with FDCs in a nonparametric framework.

6. Methodology:
A nonparametric framework based on annual flow duration curve (AFDC) and index flow duration curve will be used for estimation of the confidence intervals (CIs) of AFDCs. Considering that the quantile x_p are values of a variables X(discharge) having exceedance probability P then FDC can be described simply as a plot of x_p verses P, where P can be computed as complement of the distribution function F of X such that

$$P= 1-F(X\leq x_p)$$

To estimate index flow duration curve and CIs, the FDC are developed on annual base by considering N annual FDCs, each corresponding to one of the N years of the data. For daily data each curve is a sequence of $n=365$ values X_i with $i=1\ldots n$ arranged in ascending order $X_{1:n}\leq X_{2:n}\ \ldots X_{n:n}$, where $X_{i:n}$ is the i^{th} order statistics.

AFDCs summarizes the distribution functions of the n order statistics $X_{i:n}$ from annual minima $X_{1:n}$ to annual maxima $X_{n:n}$. Considering the average of the N values available for each $X_{i:n}$, a average AFDC, which represent a typical year wherein the interpretation is not affected by abnormal observations during the period of records. Moreover, other percentile as well as the average can be taken into account to provide α percentile of AFDCs which can be used for estimating CIs for the average.

7. Data Requirements:
Daily discharge data. Data sources would be from field organization (CWC or State Water Resources Department) and related literature.

8. Action Plan and Timeline:

S.N.	Major Activities	1st Year		2nd Year	
1	Literature review				
2	Development of annual flow duration curves (AFDC)				
3	Development of index Flow Duration Curve (Interim Report - 1)				
4	Development of a framework for estimation of CI for AFDCs.				
5	Estimation of CI for annual flow duration curves at various sites in in the region1f (Final Report).				

9. End users/beneficiaries of the Study: Central and State government departments, academicians, BIS etc.

10. Deliverables: Report/Manual, Publications

NEW STUDIES (INTERNAL)
2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/23-24

1. **Title of Study:** Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels

2. **Study group** Sushil K. Singh, Scientist F
3. **Study Period:** **One Year (**April 2023 to March 2024)

4. Objectives of study

Deriving a new closed form analytical inversion equation of nondimensional hydraulic force for channel flow with implicitly accounting the nonuniform velocity, nonhydrostatic pressure distribution over flow depth, bed friction, and turbulence. In view to very closely simulate the classical experimental data on hydraulic jump, and make it useful and handy to field engineers, practitioners and academicians.

5. Statement of problem and brief methodology

New method for the analytical solution (single term) of the three degree (cubic) equation.

6. Adopters of the results of study and their feedback

Practitioners, field engineers, and academicians.

7. Deliverables

Research report detailing the analytical inversion of hydraulic force equation and its application in exact modeling of the hydraulic jumps in rectangular channels. Publication of research papers in SCI Journals.

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. M K Goel	Scientist G & Head
2	Dr. A R senthil Kumar	Scientist G
3	Dr. Archana Sarkar	Scientist F
4	Dr. P K Singh	Scientist E
5	Dr. Manish Nema	Scientist E
6	Dr. Umesh Kumar Singh	Scientist C

APPROVED WORK PROGRAMME FOR THE YEAR 2022-2023

S. No.	Title	Study Team	Duration	Budget (in Lakh)
Completed Sponsored/ Internal Studies				
1.	Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework	P. K. Singh; P. K. Mishra; M. K. Goel; Suman Gurjar	(12/18-12/20)	NIH
2.	Real time flood modelling using HEC-RTS modelling framework	Vishal Singh; A. K. Lohani	(12/18-12/20)	NIH
3.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel; M. Arora; A. K. Lohani; D. S. Rathore (Rtd.); D. Chalisgaonkar; A. R. S. Kumar; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra	(01/16-03/22)	DST (52.15)
4.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore (Rtd.); D. Chalisgaonkar; V. S. Jeyakanthan; L. N. Thakural;	(01/16-03/22)	DST (48.83)
5.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain; A. K. Lohani; Sudhir Kumar; Praveen Thakur (IIRS)	(01/16-03/22)	DST (36.79)
6.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	Sanjay K. Jain; Sharad K. Jain (Retd.) P. K. Mishra; M. Arora; A. P. Dimri (JNU)	(01/16-03/22)	DST 80.4 (NIH) + 73.2 (JNU)
7.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	M. K. Nema; Sharad K. Jain (Retd.); Sanjay K. Jain; P. K. Singh, P. K. Mishra; P. K. Agarwal A. P. Dimri (JNU)	(01/16-03/22)	DST (54.07)
8.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra; M. K. Nema; Pradeep Kumar	(01/16-03/22)	DST (90.99)
9.	Assessment of seasonal variations in Hydrology and Cryosphere of UGB	Vishal Singh A. P. Dimri (JNU) Sanjay K. Jain	(06/19-11/22)	NRDMS-DST (23.19 Lakh)
10.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow under different climate scenarios	M. Arora P. K. Mishra Vishal Singh	(04/18-03/22)	NIH
11.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	Vishal Singh; Sanjay K. Jain; Manohar Arora	(08/20-07/22)	NIH (9.30 Lakh)

12.	Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package	D. Chalisgaonkar M. K. Goel	(08/20-07/22)	NIH
13.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	L. N. Thakural; Sanjay Kumar; B. Venkatesh M. K. Jose; T. Chandramohan	2017-2020 (Shifted to SWHD)	PDS under NHP (50.23 Lakh)
Ongoing Internal and Sponsored Studies				
1.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P. K. Mishra; P. K. Singh; P. K. Agarwal	(04/21-03/23) Shifted to Climate Hydrology Div.	NHP (9.00 Lakh)
2.	Development of Water Accounts for different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P. K. Singh; P. K. Mishra; P. K. Agarwal	(08/20-07/22) Extended up to 12/23	NHP (14.50 Lakh)
3.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh; M. K. Nema; P. K. Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (Mizoram)	(04/21-03/24) Shifted to Climate Hydrology Div.	NHP (25.00 Lakh)
4.	Monitoring of Hydrological Processes in Glaciated and Non Glaciated Watersheds of North-West Himalaya	M. K. Nema; Sanjay K. Jain; Manohar Arora; Vishal Singh; Praveen Thakur (IIRS)	(04/21-03/24)	IIRS (30.91 Lakh)
5.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Sanjay K. Jain P. K. Singh; M. Arora A. K. Lohani; Vishal Singh;	(11/19-09/23) Shifted to Climate Hydrology Div.	NMHS-MoEF (143 Lakh)
6.	Permafrost mapping and characterization of Ladakh Region	P. G. Jose (RC, Jammu) A. P. Dimri (JNU); G. Jeelani (KU); V. Agnihotri (GBPNI)	(11/19-12/23) Shifted to WHRC, Jammu	NMHS-MoEF (197.48 Lakh)
7.	Henval Experimental Watershed: Observations and modelling (Phase II)	M. K. Nema; Sanjay K Jain; P. K. Mishra; P. K. Agarwal	(08/20-07/23) Continuing	NIH (10.22 Lakh)
8.	Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin	M. K. Nema; P. K. Mishra; Rahul Jaiswal	(04/22-03/24)	NIH (9.72)
9.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in Western Ghat Region of Karnataka	P. K. Singh; Vishal Singh; Sanjay K. Jain;	(09/22-09/24)	NHP (45.0)

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-2024

S. No.	Title	Study Team	Duration	Budget (in Lakh)
Ongoing Sponsored/ Internal Studies				
1.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P. K. Singh; P. K. Mishra	(08/20-07/22) Extended up to 12/23	NHP (14.50)
2.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya	M. K. Nema; Sanjay K. Jain; P. K. Mishra	(08/20-07/23)	NIH (10.22)
3.	Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin	M. K. Nema; P. K. Mishra; Rahul Jaiswal	(04/22-03/24)	NIH (9.72)
4.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in Western Ghat Region of Karnataka	P. K. Singh; Vishal Singh; Sanjay K. Jain	(09/22-09/24)	NHP (45.0)
5.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	M. K. Nema; Sanjay K. Jain; P. K. Mishra; Praveen Thakur (IIRS)	(04/22-03/25)	IIRS (30.91)
6.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar; Jyoti Patil; Charu Pandey	(May 2022 to Oct 2023)	NIH
7.	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	A. R. Senthil Kumar; Omkar Singh; Rajesh Agarwal; N. R. Allaka;	(Sep 20- Aug 22) (extension till June 23)	NIH

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-22/02

1. **Title:** Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.

2. **Project Team:**
   Dr P. K. Singh, Scientist 'E'
   Dr P. K. Mishra, Scientist 'D'

3. **Project Duration: 02 Years (08/20 – 07/22) ***Extended till 12/23

4. **Objectives**
   The major objective of this study is to apply newly developed WA+ framework for sub-basins of Brahmaputra and Barak basins in the state of Meghalaya.

   a) To develop water accounts for the study basins/sub-basins.
   b) To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
   c) To develop accounts for agricultural services (i.e., land productivity and water productivity).
   d) To prepare the detailed WA+ report for study basins/sub-basins.
   e) To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

5. **Present state-of-the-art**
   Water accounting (WA) can provide a coherent and consistent solution to the spatial & temporal assessment of WP and the allocation of water across various competing sectors to avert the looming water crisis. WA also considers the consumption of water and the benefits and services - including ecosystem services - that result from that consumption, including the return flow of non-consumed water. Various efforts have been made by United Nations (UN), Food and Agricultural Organisation (FAO), International Water Management Institute (IWMI) and the Australian government to develop standard WA frameworks. FAO's global information system on water and agriculture (AQUASTAT) is an important source of data, however, it does not distinguish between consumptive use and non-consumptive use. The System of Environmental Economic Accounting for Water (SEEA-WATER) of the United Nations Statistics Division (UNSD) (UN, 2012) requires a variety of data from numerous sources, which are unlikely to be available at many times (Dimova et al., 2014; Perry, 2012). It does not distinguish between the green and blue water resources (Falkenmark and Rockstrom, 2006; Rockstrom and Gordon, 2001). The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) accounts for water withdrawals rather than consumptive use. However, AWAS does not provide any information on rainfed systems and natural evapotranspiration (ET) processes.

   The International Water Management Institute (IWMI) developed a WA procedure (Molden, 1997) with the aim of tracking water depletion rather than withdrawals to avoid errors when neglecting recycling, and to account for ET. The IWMI WA framework has been applied by IWMI in many irrigation system studies (e.g., Bhakra system in India (Molden, 1997); Zhanghe Irrigation System in China (Dong et al., 2004)) and at the national scale (e.g., India: Amarasinghe et al., 2007; SriLanka: Bastiaanssen and Chandrapala, 2003). However, only a few countries have adopted these WA mechanisms usually due to the lack of data needed to implement these approaches.

6. Methodology

The Water Accounting Plus (WA+) Framework is based on open access remote sensing data - in conjunction with open access GIS data and hydrological model output. WA+ communicates information on water storage, flows and fluxes for a variety of land use systems using eight intuitive fact sheets, tables and maps that are designed to be understood by people with technical and non-technical backgrounds alike.

The WA+ framework is developed by IHE-Delft in partnership with IWMI, FAO, and the World Water Assessment Program (WWAP). WA+ is based on a mass water balance approach (at the pixel level) and uses Budyko theory (Budyko, 1974) (Figure 1) and WATERPIX model (IHE, 2016) for this purpose. The basis of this water balance approach is that outflow from a certain area of interest (e.g., river basin) are explicitly related to the net inflow and depletion through a measurable ET processes.

WA+ framework classifies land use land cover (LULC) in to 80 classes. These 80 LULC classes are further grouped under four main Water Management Classes (WMC), i.e., Protected Land Use (PLU), Utilized Land Use (ULU), Modified Land Use (MLU), and Managed Water Use (MWU) (Figure 2). WA+ framework uses the Budyko theory (Budyko, 1974) for measurable ET separation in to ETgreen and ETblue. The Budyko theory is based on the coupling of (a) Water Balance approach and (b) Energy Balance approach. The water balance is performed individually for green and blue pixels, respectively.

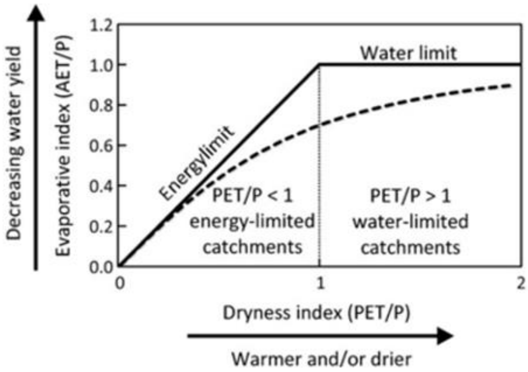


Figure 1: Budyko Framework **Figure 2: WA+ Based WMC**

6.1 Study Area and Major Input Data

The state of Meghalaya is the north eastern part of India and is bounded in the north and east by Assam plains and in the south and west by Bangladesh plains. In the north, it is bounded by Kamrup and Goalpara districts of Assam and on the east by Karbi Anglong and North Cachar. The southern border is the international border with Bangladesh which is about 496 km long. Meghalaya is located between 25º01'51.58" N to 26º07'10.31" N latitude and 89º49'10" E to 92º48'04" E longitude with altitude ranging from 50 to 1966 meters. The State covers geographical area 22,429 km^2. Figure 3 shows the basin map of the Meghalaya state. The WA+ framework makes use of open source remote sensing data in an effort to maintain a high level of transparency. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study:

- Precipitation (CHIRPS - or TRMM rainfall)
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- WA+ system based Land Use / Land Cover (WALU using GlobCover, IWMI crop maps, MODIS, FAO, etc.)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- Vegetation, leaf area index (MODIS)
- Net primary production (NPP) and gross primary production (GPP) (MODIS)

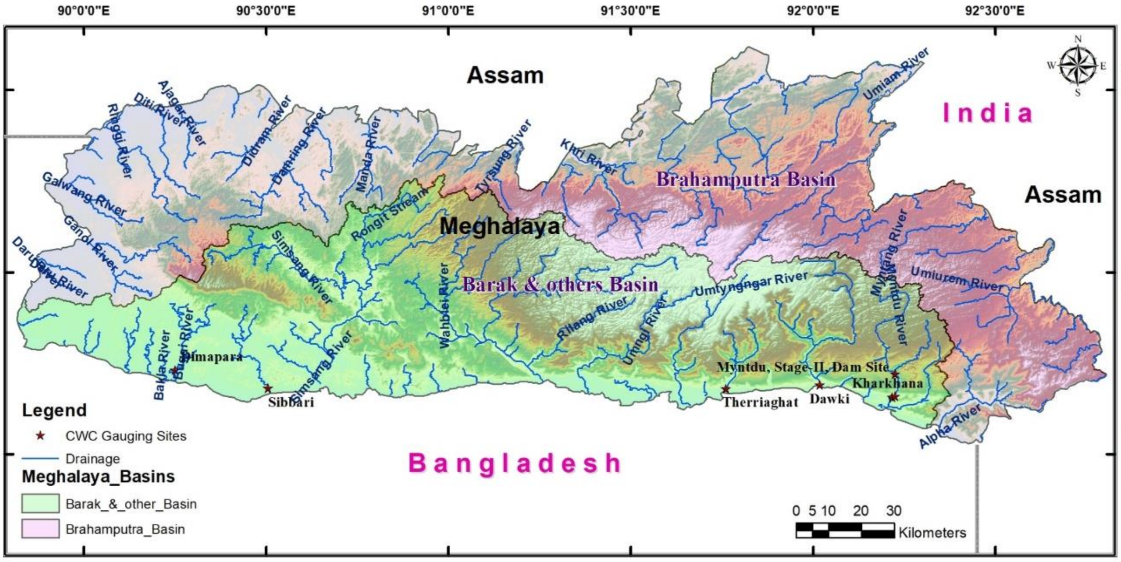


Figure 3: River basin map of Meghalaya

- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.
- GRACE (Gravity Recovery and Climate Experiment) dataset
- GMIA (Global Map of Irrigated Areas) dataset
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Grey Water Footprint/WPL datasets

7. Research Outcome from the Project:

- Water Accounts: Supply-Demand and Consumptions and Water Availability
- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Accounts for Land Productivity and Water Productivity.
- LULC map, soil maps, and river networks.
- WA+ Report and Recommendations.
- Training modules on WA+ Framework.

8. Cost Estimates:

The total cost of the project: **₹ 14.50 Lakh**

a. Source of funding: NHP
b. Sub-head wise abstract of the cost:

Head	Amount (in Lakh)		
	1st Year	2nd year	Total
1: Manpower: JRF @31,000/ + HRA and others	5.00	5.00	10.00

2: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	2.00
3: Travel Expenditure	1.00	1.00	2.00
4: Contingency	0.25	0.25	0.50
Grand Total			14.50
	Rs. Fourteen Lakhs Fifty Thousand Only		

9. **Work Schedule**
   a. Probable date of commencement of the project:
   b. Duration of the project: 02 Years

   c. Stages of work and milestone: Shown below

Project Year	**Aug. 2020-July 2021**				**Aug. 2021-July 2022 (Extended up to December 2023)**			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
a. ata downloading, processing, and generation of data base								
b. asic data analysis in WA+ framework, Ground truthing surveys for LULC and data collection from CWC, and state govt. departments								
c. A+ Framework Application and Testing								
d. Development of Water Accounts								
e. Detailed Analysis of Water Accounts and Validation and research paper publications								
f. Final report writing recommendations and Training								

10.Progress till date:

One stakeholder's workshop was conducted during November 2021 at Shillong for the WRD officials of the NE-states, including Meghalaya. We computed 7 gridded datasets (satellite and reanalysis) and compared the performance with the IMD datasets and based on the rank matrix statistics, the CHIRPS dataset is found best. We also computed extreme rainfall indices and percentage change analysis to quantify the variation in rainfall extremes between various time series durations (i.e. TS1:1983-1995, TS2:1996-2008 and TS3:2009-2021). The WaterPix (a hydrological model) was setup to prepare the inputs for estimation of the other components, such as supply and demand and water accounts.

The computations on Water Productivity and Land Productivity have been done and validated with the field data obtained from WRD Meghalaya as shown in Figure 4a&b. The computations for supply and demands (manmade and natural) and water accounts for the selected basins are in progress and the results will be discussed with WRD Meghalaya during the month October, 2023 in the stakeholder's workshop. Work on the development of a Web Portal is also in progress and the results will be presented during the workshop in the October, 2023 at Shillong with WRD Meghalaya.

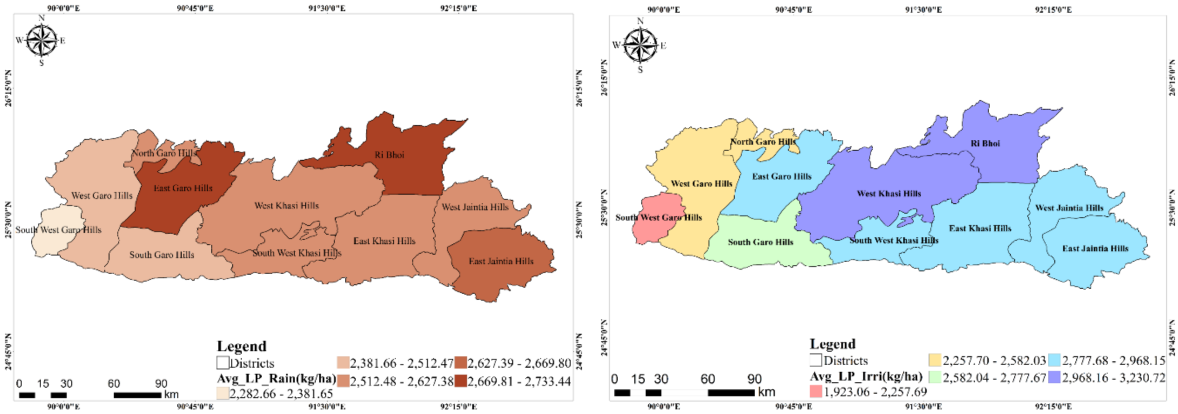


Figure 4a&b: Spatial variability of Land Productivity for the different districts of Meghalaya

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-23/05

1. **Title:** Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya

2. **Project Team:**
   Dr Manish Kumar Nema, Scientist 'E'
   Dr Sanjay K Jain, Scientist 'G'
   Dr P. K. Mishra, Scientist 'D'

3. **Project Duration:** 03 Years (08/20 – 07/23)

4. **Objectives**
   a. To develop a baseline runoff and meteorological data of Henval watershed with the established experimental setup.
   b. To carry out Hydrological modelling of Henval river
   c. To model the spatial-temporal variability and temporal-stability of the soil moisture
   d. To compare and validate the satellite soil moisture data with the in-situ observations

5. **Present state-of-art**

Watershed is supposed to be the basic unit at which the hydrologic processes are studied and is central to most of the concepts in hydrology. Experimental hydrology still has a unique place with no alternative for testing and developing new research hypotheses and models. Given the importance of experimental hydrology, NIH has initiated an experimental hydrologic project for a small lesser Himalayan watershed, namely, Henval. In the first phase of the project, a state-of-art field observatory was established with various instruments and sensors during 2016-2019. Preliminary data analysis on the estimation of evapotranspiration by various methods and water balancing of the watershed was performed. The field station developed at Henval watershed is envisaged to operate for long-term monitoring of different hydro-climatic variables. This study is supposed to be the second phase of the project.

The field monitoring of the various variables and development of baseline datasets for the Henval watershed shall be a continuous process in this study. Hydrological modeling of the stream is planned to understand the catchment characteristics and runoff behaviour of the watershed. Soil moisture is the crucial variable for partitioning rainfall into infiltration and runoff, thus playing a fundamental role in runoff modelling and flood forecasting. Recently, the scientific community is making an excellent effort to address soil moisture estimation over large areas through in situ sensors, remote sensing, and modelling approaches. There is sizeable spatial-temporal variability of soil moisture that exists in field conditions. Currently, we are able to estimate soil moisture accurately at the point scale through in-situ sensors.

Moreover, satellite sensors can obtain less accurate measurements at a coarse scale (~20 km). Finally, spatial downscaling/upscaling approaches can be used to integrate the different techniques and observations with modelling. Data assimilation and merging methods can also be considered to integrate in-situ, satellite and modelled data optimally.

6. **Methodology**

In the present study, meteorological variables, soil and runoff monitoring shall be done within the established experimental watershed. Modelling of runoff, soil moisture monitoring and modelling and comparison and validation of satellite soil moisture product with in-situ sensors are proposed. The methodology for these is described in the following sections.

Hydrologic modelling:

Several models are available for runoff modelling. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used for the estimation of streamflow in the basin.

Soil moisture modeling

The SWAT, Soil Water Balance Model, etc. shall be applied to carry out soil moisture modelling. The observed soil moisture data shall do the calibration and validation of soil moisture model. Study of the effects of static factors such as land-use, topography, soil texture, etc. on the spatial variability of soil moisture also envisaged in this study.

Validation of Satellite-based Soil moisture products

Various satellite-based soil moisture products such as ASCAT, SMAP, SMOS, etc. with different resolution shall be validated and compared against the in-situ soil moisture sensor. The interrelation of soil moisture and surface runoff shall be performed.

7. **Research Outcome from the project:**
   - Validation of the SWAT model for a lesser Himalayan watershed.
   - Assessment of the spatial-temporal variability and temporal-stability the soil moisture
   - Validation of satellite-based soil moisture product for Himalayan watershed.
   - The error characterization of the satellite-based soil moisture products.

8. **Cost estimates:**

The total cost of the project: **₹ 10.2236 Lakh**

a. Source of funding: NIH

b. Sub-head wise abstract of the cost:

SN	Sub-head	Amount (₹)			
		Year - I	Year - II	Year - III	Total
1	Salary (Part-Time Field Staff)	156000	171600	188760	516360
2	Travelling expenditure	78000	78000	78000	234000
3	Experimental/ Rental Charges	66000	76000	76000	218000
4	Misc. expenditure	18000	18000	18000	54000
	Sub- Total:	318000	343600	360760	
	Grand Total:				**1022360/-**

9. **Work Schedule:**

SN	Description of Activity	2020-21			2021-22				2022-23				2023-24	
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
1	Data Collection and up-keeping of the instruments	■	■	■	■	■	■	■	■	■	■	■	■	■
2	Hydrological modelling		■	■	■	■	■							
3	Soil Moisture modelling				■	■	■	■	■	■				
4	Satellite data acquisition, assimilation and processing		■	■	■	■	■	■	■	■	■	■		
5	Validation and comparison of							■	■	■	■	■	■	■

	satellite and in-situ data							■	■	■	■	■	■	■
6	Report writing				■				■					■

10. Progress till date:

This study is experimental in nature and a lot of instrumentation in terms of AWS, AWLR, SMS, etc. has been established in Henval catchment. The PI has regularly visited the catchment for the up keeping of filed sites and collection of hydr-meteorological data from time to time. In the previous working group meeting, the results related to soil moisture modelling using empirical models and data-driven machine learning algorithms were shared with the members. In pursuance of the study's second objective, an empirical model is formulated using available parameters in this study, i.e., rainfall, wind speed, air temperature, and near soil surface temperature. This model was calibrated and validated using the Kumargaon, Kanataal and Nagini sites in the lesser Himalayan region. It was also concluded that the learning models makes the process efficient and reliable. In the later part of the study's second objective, two deep learning hybrid models based on long-short term memory, namely, CNN-LSTM and RNN-LSTM, were developed and tested to model the sub-surface soil moisture at three stations located in a Lesser Himalayan catchment. Previously, SWAT model was setup and applied for runoff simulation at the Devnagar outlet on Henval for three years (2016-18). This time the modeling has taken into account of various hydro-meteorological data of five years (2016-20) and the results will be presented during meeting. The work is still ongoing, and findings will be shared in future working group meetings.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2022-24/06

1. **Title:** Spatio-temporal Water Availability under Changing Climate and Land-use Scenarios in Wainganga River Basin

2. **Project Team:**
   Dr Manish Kumar Nema, Scientist 'E'
   Dr P. K. Mishra, Scientist 'D'
   Dr Rahul Jaiswal, Scientist 'F'

3. **Project Duration:** 02 Years (04/22 – 03/24)

4. **Objectives**

Wide-scale interventions and other water-related activities have occurred in the Wainganga River Basin (WRB), which sustain the northern industrial region of Nagpur and large expanses of highly irrigated rice-growing districts. The water demands of the basins have steadily increased over time, and among the diverse nature of the purposes driving such a continually growing demand for drinking water, an increased reliance on irrigated agriculture, as well as numerous developmental projects such as thermal power plants, are expected to intensify competition for the limited water resources. As a result, the study's goal is to examine the basin's water resources availability and, more importantly, to estimate the influence of current and future changes of climate and landuse on the Wainganga river basin's water balance. The specific objectives of the study are as follows:

a. To study the historical climate change, morphological properties and land use/land cover change pattern over the Wainganga river basin
b. To calibrate and validate a hydrological model at different spatial scales for the river basin using current land use and observed climatic conditions
c. To develop future expected land-use change and climate change scenarios (CMIP6) for the base period and compare them with the observed period
d. To model spatial and temporal future water availability using climate and land-use change scenarios
e. To quantify the uncertainty in modeling analysis arising from model parameters and input conditions
f. To prepare adaptation/management strategies under changing climate and land-use scenarios

5. **Present state-of-art**

Presently, the total water availability of the Wainganga basin is 9225 MCM (325.89 TMC). The various sectoral demands such as domestic, industrial and agricultural for the basins water resources have grown steadily over the years, leading to an intensification of competition and conflicts for the limited water resources. Therefore, the study aims to assess the basin's water resources availability and, further, to evaluate the impact of existing and other prospective water resources developmental initiatives on the overall water balance of WRB. It is an interstate river, and the water is being shared based on the Water Dispute Tribunal Award for the Godavari Basin (Eastern Godavari Basin (EGB)). The majority of the inhabitants in this basin depend on farming, fisheries, and forest-dependent livelihood activities. The WRB fall under the parts of the Eastern Vidarbha region of Maharashtra has been in the news for many farmer suicides for more than a decade due to crop failures and increasing debts. While most districts in Vidarbha are known for cotton and soybean cultivation, eastern-Vidarbha, through which Wainganga flows, is historically known for its paddy cultivation. Bhandara and Gondia districts are known as the 'rice bowls' of Maharashtra. The rice and sugarcane production in the region was supported by the Maji-Malguzari (MM) tanks, which needs to be rejuvenated. The MM tank system, albeit feudal, was a well-designed decentralized system for irrigation and can serve as a hallmark of development in eastern Vidarbha.

6. Methodology

Study Basin:

The Wainganga rises in the Seoni District of Madhya Pradesh at an elevation of 640 m above M.S.L. Wainganga basin extends over approximately 50,000 square kilometres up to the Ashti gauging site, which spreads across the States of Madhya Pradesh and Maharashtra. The total length of this river is ~638 km up to the Ashti gauging site just before the confluence with the Wardha River. In the beginning, it flows eastward for a distance of about 175 km and then Southward for a length of about 100 km in Seoni and Balaghat District of Madhya Pradesh. It also serves as a border between Madhya Pradesh and Maharashtra state for 32km. Before joining the Godavari, it flows about 479 km in the Bhandara, Chandrapur, and Gadchiroli District of Maharashtra. The Wainganga basin lies in the medium rainfall zone, situated between 900 mm and 1600 mm. Most of the rainfall is received during the southwest monsoon from June to October. In the winter, the minimum temperature varies from 7^0 C to 13^0 C. Maximum temperature ranges from 39^0 C to 47^0 C. Month of May is the hottest month, and December is the coldest month.

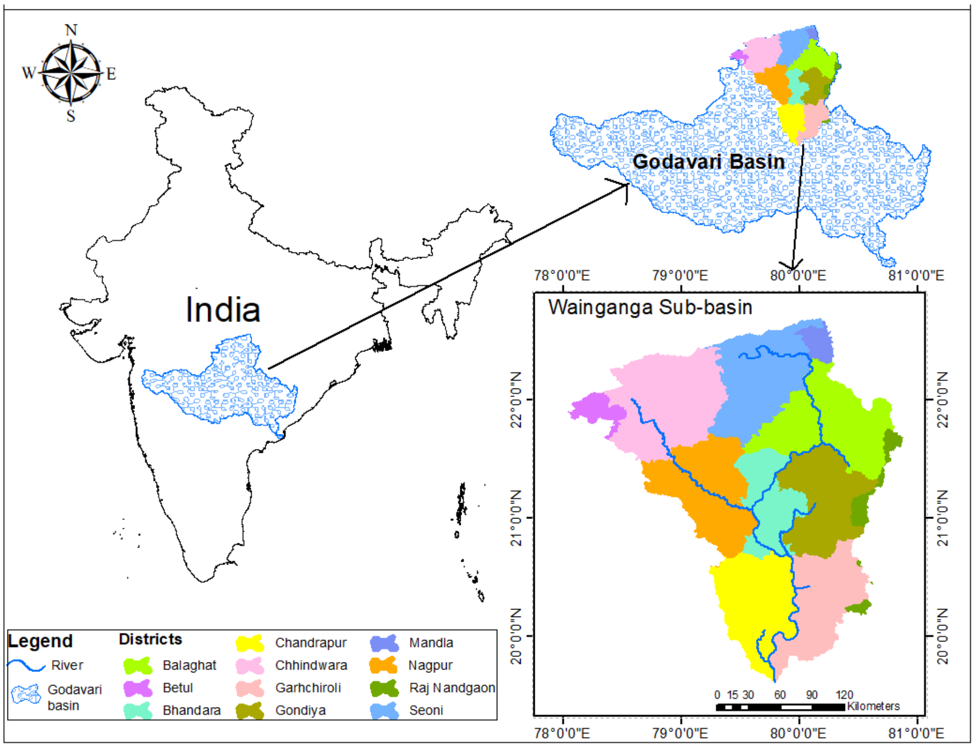


Fig. 1 Location Map of Wainganga River sub-basin of Godavari Basin in India

Research Approach:

A few activities/tasks have been defined to accomplish the study's research objectives, including collecting the data sets, field visits, surveys, analysis of collected data, model setup, scenario-based analysis, assessment of water availability, etc. The task-wise methodology proposed for analyzing the impact of climate change on the hydrology of Wainganga Basin is described below:

Task 1: Data collection, pre-processing and development of digital database including DEM, LULC, SOIL, Climatic time series, etc.

Task 2: Analysis of Trends for the climatic and hydrological extremes

Task 3: Modeling of surface hydrology and assessment of climate change impacts. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used to estimate streamflow in the basin.

Task 4: Water resources availability under changing climate & landuse scenario using the FDC based analysis. Uncertainty analysis shall be performed for the water availability assessments made using these scenarios

Task 5: Preparation of adaptation/management strategies /plans

7. Research Outcome from the project:

- Assessment of the spatial-temporal water availability under the different climatic and land-use scenarios.
- Future Land-use scenarios for the study region.
- Climate change adaptation plan for the Wainganga river Basin

8. Cost estimates:

The total cost of the project: **₹ 9.72 Lakh**

a. Source of funding: NIH
b. Sub-head wise abstract of the cost:

SN	Sub-head	Amount (₹)		
		Year - I	Year - II	Total
1	Salary (Part-Time Field Staff)	156000	156000	312000
2	Travelling expenditure	150000	150000	300000
3	Data /Infrastructure/Equipment	50000	50000	100000
4	Workshop/ Meeting / Experimental Charges	20000	200000	220000
5	Misc. expenditure	20000	20000	40000
	Sub- Total:	396000	576000	
	Grand Total:			**972000**

9. Work Schedule:

SN	Description of Activity	2022-23				2023-24			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Data Collection, pre-processing and development of digital database								
2	Analysis of trends for the climatic and hydrological extremes								
3	Landuse modeling and predictions for the future periods								
4	Modeling of Surface Hydrology and Assessment of Climate Change Impacts								
5	Water Resources availability under changing climate & landuse scenario								
6	Uncertainty Analysis								
7	Adaptation/management Strategies /Plans								
8	Stakeholder's Workshop								
9	Report Writing								

10. Progress till date:

The first task of the study has been completed in terms of collection of basic data, their pre-processing and development of digital database including DEM, LULC, SOIL, etc. The CMIP6 Data for the Wainganga basin has been downloaded and climatic series generation and their trend analysis has to be completed. For the land use land cover modeling, which is the second major objective of the study variety of spatial and non-spatial data has been collected and now the model has to be setup. For the hydrological simulation set-up of SWAT model has been attempted, but the model still needs fine tune-ups.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2022-25/08

1. Title of the Project

Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka.

2: Project Team:

PI: Dr P K Singh, Scientist 'E',
Co-PI: Dr Vishal Singh, Scientist 'D',
Co-PI: Dr Sanjay K Jain, Scientist 'G'

3. Objectives of the Study

The major objective of this study are as follows:

1. To collect, prepare and evaluate various thematic datasets such as DEM, land use/Land cover (LULC) map, soil map, and hydro-meteorological data-sets such as precipitation, temperature, discharge (if available) etc.
2. To analyze long-term hydro-meteorological variables such as precipitation, evapotranspiration, and water consumption patterns in the basin and assessment of their possible impacts on water management in the basins.
3. To estimate water potential of the west-flowing rivers, i.e., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins using hydrological models and Frameworks.
4. To assess the effects of climate and landuse changes on the water yield using Budyko conceptual framework.
5. To analyze the hydrological sensitivity and resilience capacity of the basins under adverse climatic impacts.
6. To impart training on the hydrological models to the state officials of the water resources department including IAs of NHP.
7. To prepare the detailed sub-basin wise project report for the state water resources department for planning purposes.

4: Project Duration: 02 Years (09/22-09/24)

5: The Study Area

Figure 1 shows the map of the west flowing rivers in the state of the Karnataka. As discussed above, this study is aimed to assess the water potential yields and other hydro-meteorological analysis of the six sub-basins, e.g., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins.

6: Input Data

Looking into the un-availability of the measured/monitored hydro-meteorological datasets in these basins, it is planned to utilize the earth observation and satellite datasets for calibration and validation purposes and yield estimation in this study. Following datasets (not limited to) will be used in this study:

S. No.	Data-sets/Name	Availability/Source/Resolution	Time-Period
1	DEM	SRTM/CARTOSAT – 30 m/ALOS-PALSAR 12.5 m.	
2	Daily Rainfall and Temperature Gridded (Observed)	IMDAA –12 km^2	1979-2020

3	Daily Rainfall Gridded (Satellite based-open sources)	CHIRPS – 5 km^2; TRMM+GPM -25 km2;	1991-2020
4	Other Hydro-Meteorological Datasets	NOAA/NASA/ ESA/ISRO	1991-2020
5	Population and growth Data	As per census	2011 and older
6	LULC maps	Glob cover, NRSC, IWMI, ESRI	For different time periods
7	SOIL Maps	FAO, USGS, Water Base, Future Water Group Netherlands	As per availability

A detailed information about the data sources and their resolution can be had from their respective sources.

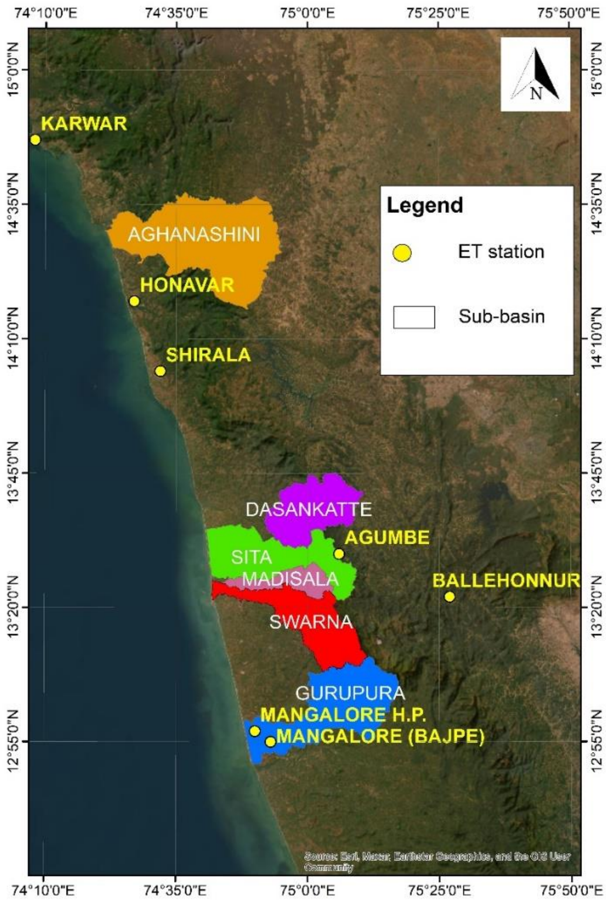


Figure - 1: West-flowing Rivers in Karnataka

7: Methodology

The modelling tools/framework such as SWAT, HEC-HMS, WA+ and Budyko based approach will be applied for quantifying the water yield potential of these basins. The study will also assess the effects of climate and landuse changes on the water yield. Along with this, the hydrological sensitivity and resilience capacity of these basins will also be assessed using the Budyko framework. For climate change analysis CMIP5/CMIP6 projections will be used in this study. For LULC change and impact assessment, decadal and projected LULC maps will be prepared and analyzed accordingly. For future projection of LULC change Markov chain based approach will be applied in this study. Figure 2 shows the flow chart of the methodology.

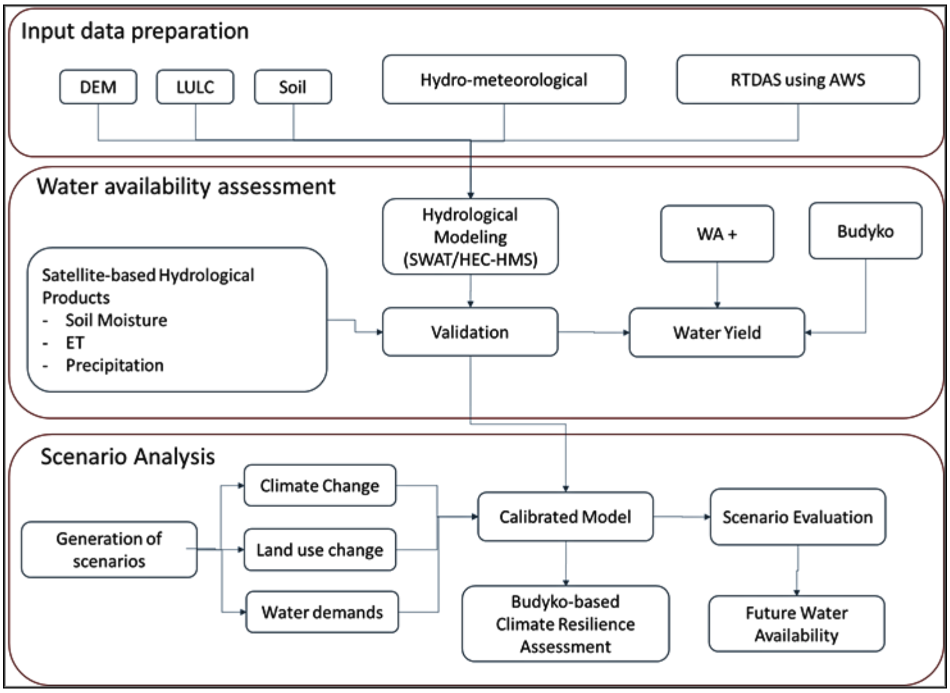


Figure 2: Modelling Framework

8. Project Budget: Year-wise breakup of the budget:

S. No.	Head	Amount (in Lakh)		
1:	**Manpower (Salaries/ wages of project staff)**	**1st Year**	**2nd Year**	**Total**
	JRF (02 nos.) as per DST Norms	8.50	8.50	17.00
2:	Travel Expenditure	3.00	3.00	6.00
3:	Meetings/Workshop	3.50	3.50	7.00
4:	Others (Hiring of services, field works, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	5.00	5.00	10.00
5:	Contingency	2.50	2.50	5.00
	GRAND TOTAL	**22.50**	**22.50**	**45.00**

9. Expected Deliverables

- Thematic maps: DEM, soil and LULC, stream network maps
- Improved and bias free high resolution gridded precipitation and ET datasets
- Basin wise water availability estimates: Historical (BAU)
- Revised basin-wise water availability estimates: CC with no LU change
- Revised basin-wise water availability estimates: LU change with no CC
- Revised basin-wise water availability estimates: both CC and LU change
- Resilience and Non-resilience basins under changing climates
- Sub-basin wise project report for the state water resources department for planning
- Training on the modelling frameworks to the state officials of the water resources department and other Implementing Agencies of the NHP.

10. Advantages, Challenges and Limitations

- The proposed modelling frameworks/tools will be very useful for estimating the water yield potential for ungauged basins using satellite and open data sources including the datasets obtained from the field.

- All satellite data products have some level of uncertainty and error which will be effectively taken care of in this study for generating error free and bias corrected datasets for future use.
- The hydrological resilience analysis will be an effective criterion to understand the historical as well as future changes in the basin to ensure the sustainability of the water resources.
- The main challenge of this study is that the study basins are ungauged hence the dependability on the satellite datasets will be on the larger side. Therefore, the alternative hydrological calibration strategies can be accounted utilizing the relevant hydrological variables such as ET and soil moisture which can be measured/estimated in the absence of the observed discharge datasets.

11. Period of Project:

- Three years from the date of the start of the project

Expected Outcome (Quantifiable Deliverables) of Key Activities with Timeline (Tentative):

S. No.	Time-Line	1st Year				2nd Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1:	Hiring Manpower followed by Inception Workshop								
2:	Data downloading and processing and generation of data bases; data collection from CWC and state govt. depts.								
3:	Analyse long-term hydro-meteorological variables								
4:	Hydrological Modelling: SWAT model								
5	**Training on the hydrological models**								
6:	Hydrological Modelling using WA+ and Budyko framework								
7:	Model's validation using satellite and other datasets								
8:	**Training on the hydrological models**								
9:	Water potential and demand assessment of the sub-basins								
10:	Hydrological sensitivity and resilience analysis: LULC and climate change followed by final workshop								
11:	**Training on the hydrological models**								
12:	Basin wise project report for the state WRD and regional conference with NHP								

12: Progress till date:

First inception workshop was conducted in March 01-03 along with the field visit with WRD officials of the Karnataka state. All the satellite dataset as mentioned in Table 1 has been downloaded and processed for final use in the modelling frameworks. All the thematic maps for all the six basins i.e., Aghanashini, Gurupur, Sita Nadi, Madisala Hole, Dasanakatte, Swarna have been prepared. In this study we processed a total of 07 satellite precipitation datasets, i.e., IMD, IMDAA, TRMM, CHIRPS, SM2RAIN, APHRODITE and Princeton at the resolution of 0.050 x 0.050 for the common period of 2007 to 2015 and compared their performance with the IMD gridded datasets. We found that the IMDAA dataset performs best as compared to the IMD dataset for all the six basins using different goodness-of-fit statistics such as NSE, RMSE, R^2, R, MAE, MSE, PBIAS. This grading of the dataset was performed using rank-grading (RG) system and Taylor's diagram. Long-term mean annual rainfall was also found to vary from basin to basin. The satellite dataset performance was found to vary from basin to basin. As an example, for Aghanashini, the IMDAA was found to be best followed by CHRIPS and other dataset. Notably, the PRINCETON dataset was found to be lowest performing in all the dataset. The work for assessment of ET and soil moisture dataset is under progress for all the six basins.

Rainfall Dataset	Source	Spatial Resolution	Temporal Resolution	Unit	Availability
IMD (Indian Meteorological Department)	https://www.imdpune.gov.in/cmpg/Griddata/Rainfall_25_Bin.html	0.25 ° x 0.25 °	1 day	mm/day	1901-01-01 to 2021-12-31
IMDAA (Indian Monsoon Data Assimilation and Analysis)	https://rds.ncmrwf.gov.in/dashboard/download	0.125° x 0.125°	1 hour	Kg/m^2	1979-01-02 to 2020-12-31
TRMM (Tropical Rainfall Measuring Mission)	https://disc.gsfc.nasa.gov/datasets/TRMM_3B42_Daily_7/summary	0.25 ° x 0.25 °	1 day	mm/day	1998-01-01 to 2022-07-31
CHIRPS (Climate Hazards Group InfraRed Precipitation with Station Data)	https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_daily/netcdf/p05/	0.05 ° x 0.05 °	1 day	mm/day	1981-01-01 to 2022-12-01
SM2RAIN (Soil Moisture to Rainfall)	https://zenodo.org/record/7950103#.ZL5j1XZByUk	0.1 ° x 0.1 °	1 day	mm/day	2007-01-01 to 2022-10-30
APHRODITE (Asian Precipitation-Highly-Resolved Observational Data Integration Towards Evaluation)	http://aphrodite.st.hirosaki-u.ac.jp/download/	0.25 ° x 0.25 °	1 day	mm/day	1951-01-01 to 2015-12-31
Princeton	https://maps.princeton.edu/catalog/stanford-ht243pf0791	0.25 ° x 0.25 °	1 day	Kg/m^2/sec	1948-01-01 to 2016-12-31

We also assessed the water yield potential of the Aghanashini basin taking it as fully ungauged. For this purpose, we took the GLDAS ET and ESACCI Soil Moisture as the surrogate measurements for calibration and validation of the SWAT model. Figure 3 shows the grids of these datasets in the Aghanashini basin.

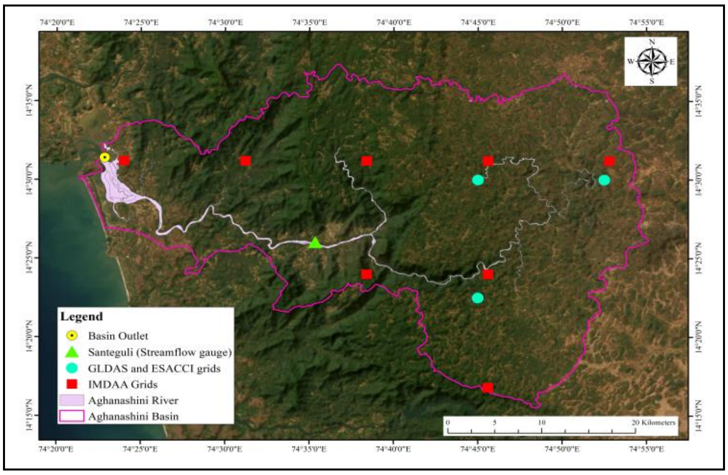


Fig. 3: Grids of GLDAS ET and ESACCI soil moisture dataset in Aghanashini River Basin

Figure - 4 shows the long-term monthly average of the water yield of the Aghanashini basin by using the ET and soil moisture (SW) datasets.

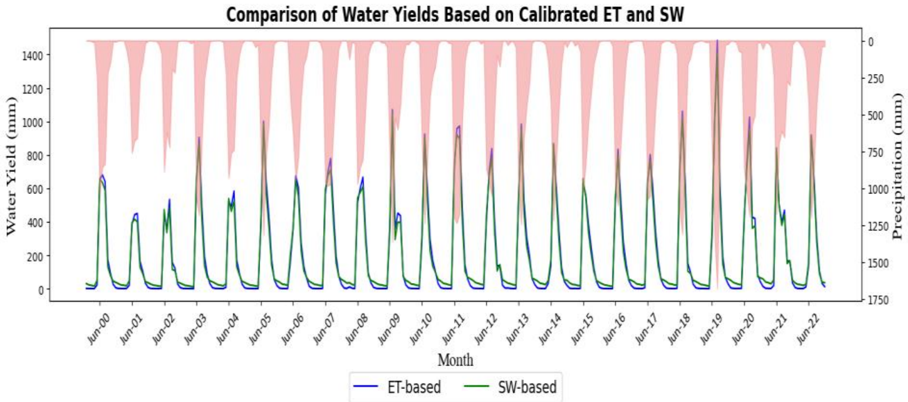


Figure - 4: AET and soil moisture-based average monthly water yields of the basin

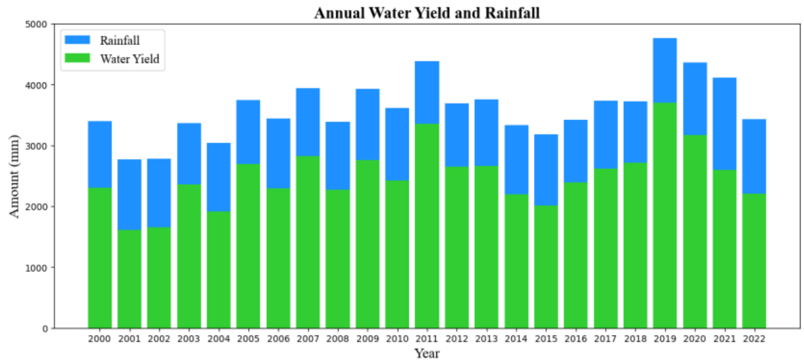


Figure - 5a: Annual average water yield of the Aghanashini basin from AET-based SWAT model (period: 2000 to 2022)

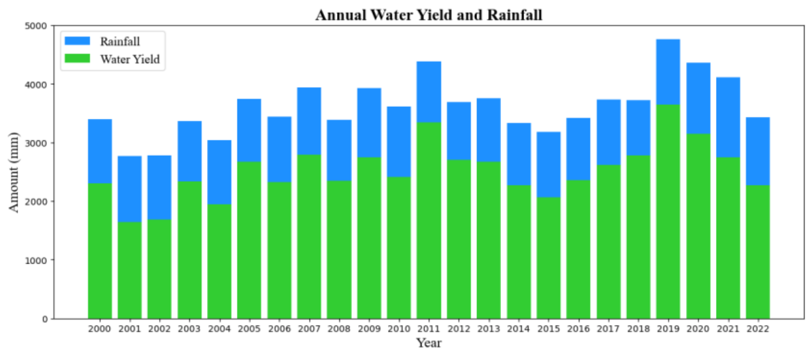


Figure - 5b: Annual average water yield of the Aghanashini basin from soil moisture-based SWAT model (period: 2000 to 2022)

A comparison between the simulated and observed (extrapolated at the basin outlet using the gauge dataset at Santeguli) monthly water yields for the Aghanashini basin is shown in Table - 2.

Table - 2

Comparison between the observed and simulated water yields (monthly scale)

Mean (mm)			R^2		NSE		PBIAS (%)	
Observed	Simulated							
	ET-based	SW-based	ET-based	SW-based	ET-based	SW-based	ET-based	SW-based
250.95	219.16	220.73	0.74	0.702	0.716	0.67	12.67	12.04

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2022-25/07

1. **Title:** Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya

2. **Project Team:**
   Dr. Sanjay K. Jain, Scientist 'G'
   Dr Manish Kumar Nema, Scientist 'E'
   Dr P. K. Mishra, Scientist 'D'
   Dr. Praveen Thakur (IIRS)

3. **Project Duration: 03 Years (04/22 – 03/25)**

4. **Scope of the Work**

The scope of the work to be carried out in the project includes:

a. Characterizing spatial extent and patterns of hydrological cycle components in selected watersheds in Western Himalaya (Uttarakhand) using multi-scale EO data;
b. Assessment of watershed's topographical, morphological and hydro-meteorological spatio-temporal dynamics using a systematic and multi-site sampling using ground observations and EO inputs;
c. Determining the EO-based land surface parameters and hydrological cycle variables of the watersheds and its dynamics;
d. Developing hydrological models for multi-scale assessment of hydrological cycle components and water availability linking natural hydrological processes and anthropogenic water use under present and future climate scenarios;
g. Developing a web-based hydrological information system, supporting hydrological and spatial database, web analytics and data/information dissemination for water resources planning and management.

5. **Deliverables**

- Establishment of long term, experimental watershed monitoring sites with field instrumentation for understanding various hydrological and snow/glacier processes which are important in overall water balance studies.
- The updated geospatial-database on hydrological sources and water resources of the selected watersheds.
- Quantification of hydrological response of the selected watersheds and assessment of basin level water availability in the Upper Ganga Basin of NWH region under present and future climate change scenarios.
-

6. **Cost estimates:**

The total cost of the project: **₹ 30.91 Lakh**

a. Source of funding: IIRS
b. Sub-head wise abstract of the cost:

Head	Total grant (Lakh)
Recurring	
(i) Salary + HRA: 01 JRF or Project Fellow	**10.88**
(ii) Field work and Travel (Domestic)	**6.5**

(iii) Services (Field activities & other project costs: Field sampling for hydrological data collection and lab analysis of soil/water samples; contingency/consumables, skilled/non-skilled labor hiring for watersheds data collection), data, printing of project report/outputs and other charges.	**9.5**
(vi) Institutional charges/ Overhead	**4.03**
Grand Total*	**30.91***

Say **Rupees Thirty Lakh Ninety-One Thousand and Two Hundred only** from IIRS. *This is the maximum amount, which can be transferred during project duration. Actual budget transfer to be as per actual funds availability from ISRO, progress of work and utilization of given funds by the collaborating institute.

8. Project Schedule

Duration of project shall be **Three (03)** years from the date the project has been sanctioned by ISRO and approval of budgetary provisions.

Activity	**Year I**	**Year II**	**Year III**
Project initiation, Inception workshop			
Recruitment of project personnel			
Permission for field studies			
Workshop for field training			
Field instrumentation/sampling			
Acquisition of Satellite based Earth Observation data			
Progress review/workshop			
Hydrological data collection, development of web based data repository and information system			
Development of hydrological models for multi-scale water resources availability			
Generation of spatial layers on hydrological fluxes for present and future climate scenarios			
Progress review and stakeholder workshop			
Final Report generation			

09. Progress till date:

- A workshop (online) was conducted to sensitize the project partners regarding the project outlines and deliverables by IIRS.
- A JRF has been recruited as provisioned in the project
- A Two-day training and exposure Programme was organized for all the SRFs/JRFs during 19-23 December, 2022 at IIRS, Dehradun.

A joint field visit was conducted by NIH, Roorkee and IIRS, Dehradun to identify suitable sites for installation of AWS and equipments under the non-glaciated watershed component.

ONGOING STUDIES (INTERNAL)

Title of the Study
Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics

Study Team	Dr. Archana Sarkar, Sc F, SWHD (PI) Dr Jyoti Patil, Sc E, NIH New Delhi office (Co-PI) Mrs Charu Pandey, A.L.I.O., Library (Co-I)
Type of Study	Internal
Date of Start	1 May 2022 Scheduled date of completion 31 Oct 2023

Study Objectives:

- To study and analyze the growth and direction of research in the field of climate change impacts on hydrology and water resources in India during 1992-2021
- Identification of gap areas and emerging areas in the research on climate change impact on hydrology and water resources to address the water security issues in India
- Evaluation of research productivity of institutions engaged in research on climate change impact on hydrology and water resources in India through scientometrics
- Dissemination of study findings through workshop/training course, scientific documentation and other outreach means.

Background
Scientometrics is considered a powerful tool of tracing the development of a given scientific field, thereby revealing the gap areas and emerging research problems, and evaluation of scientific contributions and research productivity of research community, institutions, regions, countries, etc. As technological advancements occur, there is a paradigm shift in the working trends in any field. So it is recommended to look for emerging trends and propose new developments when the current trends of any research domain are studied. Bibilometric analysis and scientometric mapping can show the change in mindset of researchers by studying the research works over a time period. Also by identifying the research questions in the water sector today, one can have insight into the future of research in the field. As Boyack et al. (2005) stated that a correctly constructed science map help to understand the inputs, associations, flows and output of science and technology: “Just like in physical world, maps help us to understand our environment- where we are, what is around us and the relationships between neighbouring things”. In recent years, scientometrics has come to play a major role in the measurement and evaluation of research performance.

Potential climate change and its unfavourable impacts on hydrologic systems pose a threat to water resources throughout the world. As per the latest report of IPCC (AR6) released in August 2021, it is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost.

The effect of climate change on hydrology in tropical Asia has many facets. The Himalayas, which act as a mountain barrier on the earth, where polar, tropical and Mediterranean influences interact, play an important role in maintaining and controlling the monsoon system over the Asian continent. In the Himalayas, the storage of precipitation in the form of snow and ice (in glaciers) over a long period provides a large water reservoir that regulates annual water distribution. As a populous, tropical developing country, India faces a bigger challenge in coping with the consequences of Climate Change than most other countries. It is now clear that enhanced climate variability and climate change due to continued emission of greenhouse gases in the Earth’s atmosphere will alter the key characteristics of summer monsoon rainfall and could significantly impact water supply and demand throughout the Indian subcontinent. Continued global warming is projected to further intensify the global water cycle, including its variability, and the severity of wet and dry events. Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes. There is a strong need to reconnect climate science and policy development with the local context to generate relevant knowledge supporting future climate change adaptation and disaster risk reduction strategies on a local to national to international level. The ability to undertake policy action requires information, knowledge, tools, and skills.

Statement of the problem

Many researchers/academicians/policy makers in India have studied and published various aspects of climate change impact on hydrology vis-à-vis water resources and policy implications. However, such studies have been carried out in isolation focusing on specific region/river basin and specific aspect of climate change impact (floods/droughts/water availability/etc). As such, a scientometric analysis of research on climate change impact on hydrology and water resources by Indian scientists has not yet been carried out. The proposed study is expected to highlight the gap areas, emerging trends, and potential opportunities in taking forward the research on climate change impact on hydrology and water resources, which is gaining momentum in view of the looming water scarcity. The study will provide an insight into the dynamics of research on climate change impact on hydrology and water resources and also provide a roadmap to the policy planners in India to address the Sustainable Development Goals (SDG).

Approved Action plan and timeline

S. No.	Work Element	First Year				Second Year	
		Q1	Q2	Q3	Q4	Q1	Q2
1	Identification of computational tools						
2	Identification of search strings relevant to research on climate change impact on hydrology and water resources in India						
3	Data collection from various sources						
4	Bibliometric analysis using bibliographic databases						
5	Manual analysis by searching and analyzing data from websites						
6	Scientometric mapping						
7	Interpretation of bibliometric analysis						
8	Preparation of research publications, outreach material, and synthesis report						

Progress

Scopus cited research database (1992-2021) by Indian authors in for the 'Hydrology' and 'Climate Change' keywords was collected from Library of Indian Institute of Technology (IIT), Roorkee. The 31 years Scopus database includes research papers, book chapters, conference papers, review articles, books, editorials, short surveys, and conference proceedings. The collected data were processed and analyzed in R-biblioshiny package to extract the preliminary results related to hydrology- climate change research in India.

The main information of the collected data includes the authors contribution to the research articles (single authored, multi- authored, authors per document, Co-authors per documents etc.). The average citations per documents and collaboration index of the research was also highlighted in the main information. The other results of preliminary analysis of Hydrology-Climate Change (CC) database includes most cited documents, most relevant documents, word cloud and thematic evolution. The Word Cloud result showed that research in the hydrology along with climate change are mainly focused on climate models, water supply, hydrological modelling, water resources, environmental monitoring, rainfall, runoff, rivers, evapotranspiration and hydrological response etc.

The thematic evolution observed in the research database from 1992 to 2021 shows that in the recent database, the research is not limited to studying the parameters or impact of climate change on hydrology, monsoon patterns and groundwater but impact on humans and environment were evolved in research. Important findings about the most relevant sources of research information, productivity of institutions, thematic evaluation and world collaboration are shown below:

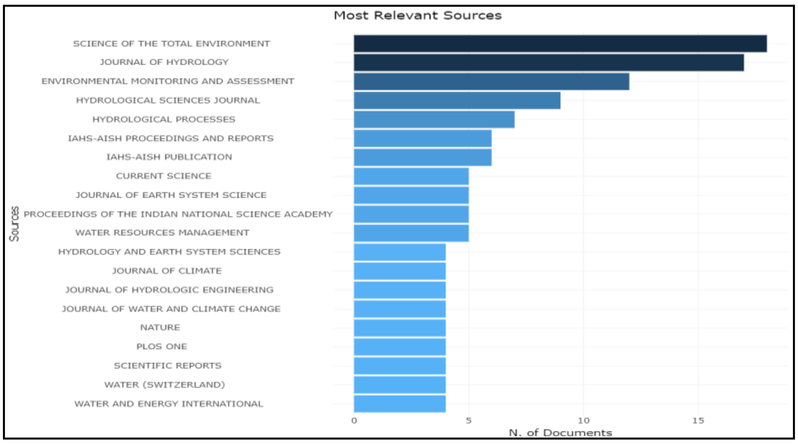


Figure 1: Most relevant sources

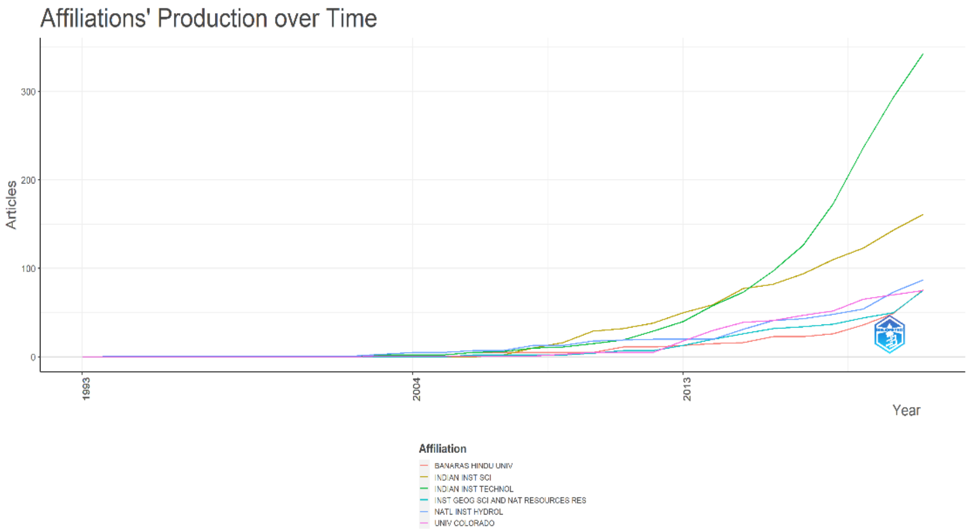


Figure 2: Productivity of Institutions in India

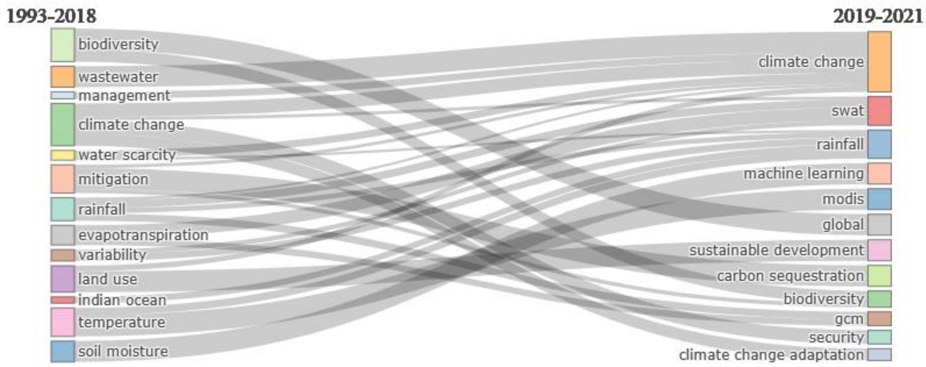


Figure 3: Thematic Evaluation

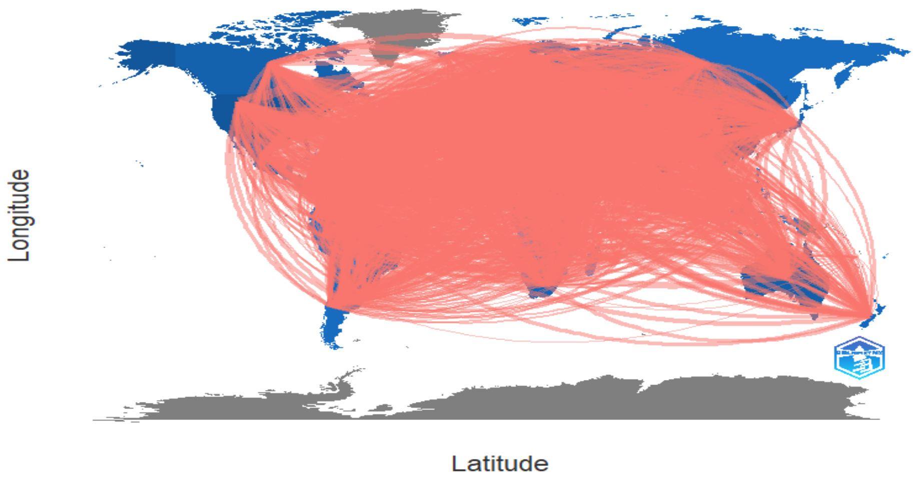


Figure 4: World Collaboration

Deliverables
Research papers, synthesis report, policy brief

End users/beneficiaries of the study
Research Organizations, Academic Institutes, Central and State Government Agencies, Policy Makers, NGOs.

Future Plan
As per the approved/proposed action plan.

ONGOING INTERNAL STUDY

1. **Title of the Study:**
   Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana

2. **Study group:**
   Dr. A. R. Senthil Kumar, Sc "G" WRS
   Sh. Omkar Singh, Sc "G", RMOD
   Sh. Rajesh Agarwal, PRA, RMOD
   Sh. Nageswara Rao Allaka, SRA, RMOD

3. **Date of start:** September 2020

4. **Duration of the study**: 2 Years *(Request to extend up to June 2023)*

5. **Whether externally funded or not:** Internal

6. **Objectives:**
   a. To evaluate the existing cropping pattern and farming practices for estimation of farmer's income
   b. To carry out scenario analysis considering combinations of crop types and cropping pattern, land allocation, water allocation under climatic variability, etc.
   c. To develop plan for optimized income from farming practices encompassing food and water security.

7. **Statement of the problem**

The rising population and industrial growth with climate change makes difficult to meet the demand of agricultural activities. Continuous over exploitation of ground water under uncertain occurrence of rainfall is inevitable to continue the traditional cropping pattern. Traditional cropping pattern is neither good for soil health nor for food security. Farmer's income is often below optimal. Scientific planning considering cropped area, climate smart crop types, crop productivity, cropping pattern, farming input costs, and crop revenues, will evolve optimal utilization of available water and optimize farmer's income from farming practices. Scenario analysis with projected population growth, landuse changes, climatic conditions, water-efficient irrigation technologies, etc. shall provide a canvas of options to be considered for optimal income from farming practices in future. A scientific plan is needed to guide the farming community about optimizing their income from farming practices that lead to food and water security.

8. **Methodology**

The optimal income from agriculture for various scenarios of crop types and land resources in Mewat region, Haryana is evolved by setting up of WEAP tool with the combination of LINGO. The inputs to WEAP tool such as water demand from various sectors, priority of the demand, catchment details, hydrologic conditions and inflows, catchment hydrology (river flow, ground water, lakes/reservoir/storage tanks, springs, other storage structures etc), supply preference (operating rules/policy), return flows, minimum flow requirements, economic variables such as cost of water transmission etc. are prepared from the data obtained from various sources such as irrigation department, IMD, CWC and census department. The future climatic scenarios will be downscaled from GCM models for SSP245 and SSP370. The hydrological processes occurring in the catchment will be modeled and will be compared with the measured discharge time series. After the proper calibration of the model, the demand sites will be added into a model framework and different scenarios will be generated to assess the gaps in the water demand and supply and water availability at different locations and at the different period of time. The optimum income for agricultural sector will be arrived by LINGO using the input variables obtained from the scenario analysis of WEAP model for crop types and land resources. The optimization functions such as maximizing the net income from agriculture, minimizing the water usage, minimizing the cost of cultivation with the constraints of land area for crops, water availability based on the scenario analysis and cost of cultivation are considered for achieving the objectives. The scenarios such as change of cropping pattern (crop diversity) considering food security, change of cropping area with allowable limits, availability of water (normal, dry, very dry, wet and very wet), industrial and population growth and climate scenarios SSP245 and SSP370 from GCM models.

9. **Results achieved with progress/present status:**

Three blocks, Nuh, Nagina and Punhana of Mewat District have been selected for the setup of WEAP model based on the drainage network created from the toposheets of Survey of India. The total area of three blocks is 957.78 Sq.km. The total population by the end of 2020 is 7,71,093 (Urban- 80101 and rural - 690992) based on the 2011 census and the population projection of Haryana State by National Commission on Population. The gridded data of rainfall, maximum and minimum temperature have been obtained from IMD. The evapotranspiration has been estimated by Hargreaves method using the average maximum and minimum temperature and extra terrestrial radiation obtained from the following web-site: https://www.engr.scu.edu/~emaurer/tools/calc_solar_cgi.pl. The crop area under Kharif and Rabi, livestock details of Nuh, Nagina and Punhana have been collected from and the Agriculture department and Animal Husbandry and Dairying Department, Nuh. The crop water requirement for Kharif and Rabi crops have been taken from literature. The monthly water consumption by rural and urban population is estimated by assuming daily consumption for rural and urban population as 70 lpd and 135 lpd respectively. The monthly consumption by the livestocks is estimated from the details derived from literature. The percentage share of landuse for agricultural land, forest land, settlement, fallow land and water bodies are 74, 8, 12, 5 and 1 respectively. The monthly crop coefficient (Kc) for different landuses and crops and the effective precipitation for evapotranspiration are estimated based on the literature and FAO report. The yield and market price of the Kharif and Rabi crops are obtained from literature. The ground water draft for all uses is taken from the CGWB report of 2012 for Mewat District. The cost of cultivation for major Kharif and Rabi has been obtained from the report of Directorate of Economics and Statistics, Ministry of Agriculture and Farmer Welfare for the year 2018-19. The cost of cultivation for Sorghum (dry fodder) and Brinjal (Kharif) and Berseem (green fodder) and Cauliflower (Rabi) have been obtained from SPACE Team (Dr. S. S. Grewal). The WEAP model is run with the inputs generated from different sources and literature for normal, wet, very wet, dry and very dry, population growth scenarios to find out demand and supply gap. The LP model is setup with objective functions of maximizing the farming income, minimizing the water usage and cost of cultivation with inputs from WEAP model and other constraints for crop area, yield and cost of cultivation for all the scenarios to evolve optimal crop area. The average precipitation, maximum and minimum temperature for SSP245 and SSP370 for the CMIP6 models, ACCESS-CM2 and ACCESS-ESM1-5 are extracted from the archive of NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) for the period from 2015 to 2100. Extension of the study upto June 2023 is requested to setup the WEAP model with the data of scenarios SSP245 and SSP370 of ACCESS-CM2 and ACCESS-ESM1-5.

10. **Research outcome from the study**

The following are outcome from the study

- Maximum net profit, minimum investment cost and minimum water usage for each scenario.
- Optimal land allocation for different crops (considering staple food, nutrition value), Kharif season and rabi season for each scenario.

CLIMATE HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sanjay K Jain	Scientist G & Head
2	Dr. Manohar Arora	Scientist F
3	Dr. Ashwini A. Ranade	Scientist D
4	Dr. P K Mishra	Scientist D
5	Dr. Vishal Singh	Scientist D
6	Dr. Sunil Gurrapu	Scientist D
7	Dr. Deepak Singh Bisht	Scientist C
8	Dr. Akshaya Verma	Scientist C
9	Sh. Rajat Kumar	Scientist B
10	Sh. Jatin Malhotra	PRA
11	Sh. Madhusudan Thapliyal	SRA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हि ष्ठा मयोभुवः

CLIMATE HYDROLOGY DIVISION

About the Division

Climate change has a wide range of impacts on water resources, affecting their availability, quality, and reliability. Climate change is causing, rising temperatures, and spatio-temporal shifts of precipitation more severe, unpredictable weather are likely to affect rainfall and its distribution, as well as river flows and groundwater, and impaired water quality. To handle and manage the above issues of climate change, a Climate Hydrology Division has been created in the Institute. The purpose of creation of this Division is to have a branch of scientific research that focuses on the study of the interactions between climate and the hydrological cycle. A Centre named as Centre for Cryosphere and Climate Change is part of the Division. The focus of the Centre is to study the impact of climate change on water resources of the Himalayan region.

Vision & Mission

Addressing the challenges posed by climate change to water resources requires a multi-faceted approach. The vision behind the Climate Hydrology Division is to advance scientific knowledge and understanding of the complex interactions between climate and the hydrological cycle. The division aims to contribute to the development of sustainable water resource management practices, adaptation strategies, and policies in the face of climate change. The vision and mission of the Division are:

- Investigating the impacts of climate change on water availability, water quality, and water management. This involves studying changes in precipitation patterns, temperature, evaporation rates and river flows in response to climate variability and long-term climate change.
- Developing and improving hydrological models, data analysis techniques, and decision support tools to simulate and predict hydrological processes under changing climate conditions
- In Himalayan region, rising temperatures lead to reduced snow accumulation, earlier snowmelt, and accelerated glacial melting. Simulation of the behaviour of snow and glaciers under different climate scenarios and aid in predicting the impacts on water resources, river flows, and water availability.
- Collaborating with national and international organizations, research institutions, and stakeholders to foster interdisciplinary collaboration and knowledge sharing in the field of climate hydrology.
- Contributing to capacity building efforts by providing training, education, and knowledge transfer to researchers, professionals, and decision-makers in the field of climate hydrology and water resource management
- Providing climate information and predictions to support water resource management, decision-making, and adaptation strategies. This includes developing tools and methods for communicating climate information effectively to policymakers, water managers, and other stakeholders

Overall, the vision behind the Climate Hydrology Division is to have advance scientific knowledge, support decision-making processes, and promote sustainable water resource management in the face of climate change. By conducting research, developing models, and providing climate services, the division aims to contribute to a more resilient and adaptive approach to managing water resources in a changing climate.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2023-24

Sponsored/ Internal Studies (Completed)

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
1.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora; P K Mishra; Vishal Singh	3 years (04/21-03/23)	NIH
2.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	Vishal Singh; Sanjay K. Jain; Manohar Arora	2 years (08/20-07/22)	NIH (9.30)
3.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Vishal Singh; Sanjay K. Jain; A P Dimri (JNU)	3 years (06/19-12/22)	NRDMS-DST (23.19)

Internal R&D Studies (Ongoing)

S.N.	Title	Duration	PI
1	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	3 years (04/22-03/25)	Ashwini Ranade
2	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	2 years (04/22-03/24)	Sunil Gurrapu
3	Monitoring and Modelling of Gangotri (Bhojwasa) watershed under different Climate Scenarios	3 years (04/23-03/26)	P. K. Mishra
4	Glacier recurrence survey, Instrumentation and Modeling to study the Batal Glacier in part of Western Himalaya, India	5 years (04/23-03/28)	Vishal Singh

Ongoing
Sponsored Studies

S.N.	Title	Sponsoring Agency	Duration	Cost (Lakhs)	PI
1	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	NMHS-MoEF	11/19-09/23	143.00	Sanjay K. Jain
2	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	NHP	04/21-06/23	9.00	P. K. Mishra
3	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	NHP	04/21-03/24	25.00	Vishal Singh
4	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	IIRS	04/22-03/25	30.91	Sanjay K. Jain; M. K. Nema

Brainstorming session/ Awareness programme:

1. 1st Steering Committee meeting for the Monitoring of Glaciers organized at Institute of Hydrology, Roorkee on May 02, 2023.
2. Workshop on "Climate change impact and Adaptation in the Water sector in India" organized at NIH, Roorkee on October 25, 2021.
3. Brainstorming workshop on "Preparation of Guidelines for Management of Glacial Hazards & Risks especially GLOF & LLOFs" jointly with NDMA, Delhi during June 23-24, 2020 (Online).

Laboratories/ Centre:

The "**Centre for Cryosphere and Climate Change Studies**" is attached with the Division. The Background, Vision and Objectives of the Centre are given below.

Background

Snow and glaciers covered area play an important role in the hydrology of glaciered basin. The permanent snow and glacier fields of the Himalaya act as a critical fresh water reservoir that release large quantity of freshwater throughout the year. The water yield from high Himalayan basin is considered as a dependable source of water supply for drinking, irrigation, hydroelectric power generation and for other miscellaneous purposes like recreation etc. All the major south Asian rivers originating from the Himalayas are fed by the snow and glaciers melt water. Geographically from west to east, the Himalaya has been categorized in three parts, i.e., Western Himalayas, the Central Himalayas and the Eastern Himalayas, on the basis of their latitudes and topographic features. The Indian part of Himalaya has three main river systems namely; Ganges, Indus and Brahmaputra, which are the lifeline of millions of people of northern India.

The snow cover in the Himalaya varies from western to eastern Himalaya and subsequently affect the flow regime of the rivers. The northern part of western Himalaya receives more snowfall and less rainfall as compared to eastern Himalaya, where the rainfall contribution is significant. Along with the seasonal snow Himalayan glaciers are also have huge storage and very important source of fresh water. In the Himalaya, approximately 33,000 km^2 area is covered by the glaciers of varying shapes and sizes. With a total number of 9,600 glaciers, the Indian Himalaya has one of the largest concentrations of glaciers after the Polar Regions.

The streamflow in Himalayan rivers is induced by a combined form of rainfall and snowfall and glacier-melt runoff. Melting from high Himalaya snow cover during early summer is a paramount source of water for many rivers originating from the Himalaya. It is roughly estimated that approximately 10 to 20% Himalayan area is covered by glacier ice, and about 30 to 40% area is covered by seasonal snow cover. The runoff from partially glaciered basin is characterized by extended lean flow season from October to February. The flow gradually increases during March and April with the snowmelt and advent of summer, and reaches higher levels of discharge during July and August.

Regional hydrologic studies suggest a decreases in snow and ice extent over the coming century will be most detrimental in the Indus and Brahmaputra watersheds because glacier runoff plays a significant role in these basins. It has been projected that ∼30%–88% of the present glacier ice volume could vanish in the Himalaya, indicating a major threat to water resources by 2100. To handle these issues, a Centre for Cryosphere and Climate Change Studies has been started at NIH.

Vision

The vision behind creation of Centre is to facilitate the effective management of snow and glacier resources in the country to address the concern of water availability. The proposed Centre is aimed to take care of issue of water availability in future under climate change scenarios. Snow and glacier change dynamics vis-a-vis climate change will also be area of concern of the Centre.

Objectives

The **Centre for cryosphere and climate change studies** have the following objectives:

- To foster, promote and sustain a scientific culture in the snow and glacier studies including impact of climate change.
- Development of a novel framework for ensemble simulations by integrating different snow-glacio hydrological models to account the overall water balance including snow and glacier melt runoff.
- Assessment of changes in snow-glacier dynamics and their impacts on melt runoff.
- Analysing the impact of climate change on snow-glacier hydrology in Himalaya utilizing CMIP5/CMIP6 multi-model experimental scenarios.
- To collaborate with Indian and International research organisations/ universities, including Southeast Asian and SAARC member countries, on snow and glacier research.
- To collaborate with State governments and the other organisations working in the area of snow and glacier studies in organising workshops, awareness and trainings on snow and glacier aspects.
- To provide consultancy to the users and hydro-electric project (HEP) implementing agencies / authorities in safe designing of project.
- To help building bridges among other research groups, academia, policy makes, and general public to pioneer new approaches.
- Long term planning for water sustainability under climate uncertainty in the downstream regions through hydro-climatological modelling in Himalaya.

ONGOING STUDIES (INTERNAL)

Title of the Project: Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes

Thrust area under XIIth Plan: Impact of climate change on water resources and hydrology of extreme

Project team: Dr. Ashwini Ranade, Scientist 'D' (PI)
Dr. P.K. Mishra, Scientist 'D' (Co-PI)
Dr. Sunil Gurrapu, Scientist 'D' (Co-PI)

Type of Study: Internal

Status: New Study

Duration: 3 years

Date of Start: 1 April 2022

Scheduled date of completion: 31st Mar 2025

Objectives:

- To document broad features and unique characteristics of the large-scale and isolated heavy rainstorms/snowstorms across Northwest Himalaya. *(Completed)*
- To generate in-depth information about the location, shape, size, and intensity of the various rain-producing weather systems that are formed over the northwest Himalaya during different seasons of a year. *(Ongoing)*
- To investigate the relationship among global atmospheric thermal structure and general and monsoonal circulation features and seasonal extremes over the NW Himalaya. *(Ongoing)*
- To study the nature of mid/upper tropospheric tropical-extratropical interactions and different thermo-hydrodynamical processes causing isolated heavier rain/snow storms. (*Ongoing)*

1. **Statement of the problem:**

Heavy rain events over the northwest Himalayan region are becoming ferocious in recent years causing catastrophic disasters. Colloquially termed as the cloudburst has a potential to downpour over a smaller region in very short duration. International disaster database (http://www.emdat.be) has reported the substantial increase in the extreme rain events over the western Himalayas in recent 30-40 years. It is one of the most studied but less understood phenomena so far. Under the influence of highly complex terrain and tropical-extratropical interactive atmosphere, the northwest part of Himalaya becomes more prone to such types of extreme events, especially during the monsoon season. There is a widespread belief that, in a recent global warming period, due to the intensification of the hydrological cycle, extreme rain events are increasing (Senior et al. 2002, IPCC 2007). The sixth assessment report (IPCC, 2021) projected that, extreme rainfall are projected to be intensifies by 7% for each additional 1 ºC due to acceleration of hydrological cycle in warmer climate across the globe and become more frequent mostly in Africa and Asia. Since 2010, about 17 noticeable extreme events have been observed over Indian Himalayan region of Leh, Uttarakhand, Jammu and Kashmir and Himachal Pradesh, about 5 over subtropical Pakistan and 2 each over Nepal and China. Studies shows that, multiple visualizable factors operated in accord to produce extreme weather/rain events across subtropical Asia. Unprecedented interactions between deep westerly trough and cross-equatorial Indian Ocean south-westerlies as well as Pacific easterlies results in evolution of large and intense monsoon trough extending from Philippine through Indus basin. Arabian sea and Bay of Bengal provides the excessive moisture and numerous synoptic scales, mesoscale and microscale weather systems are evolved and interconnected in the anomalous monsoon trough along with topographical features results in increase in the severity of the events. Formation and intensification of troughs in the temperate westerlies is a short period phenomenon. Therefore, condensation and intense rainfall in subtropical mountainous terrain that involving confluence and convergence of huge airmasses of contrasting characteristics are short lived

In this study, we propose a detailed systematic analysis of various heavy rainstorm events over northwest Himalaya during winter, pre-monsoon, monsoon and post-monsoon seasons of a year on case by case basis by using the available station (hourly) and gridded (daily) rainfall observations and reanalysis atmospheric parameters (temperature, pressure, geopotential height, precipitable water, wind, absolute vorticity, cloud cover, vertical velocity, freezing level, OLR etc.)

2. Dataset used:

- Rainfall Data: Gridded rainfall products from IMD; hourly rainfall data of selected stations across NW Himalaya
- NCEP-CFSR dataset (2.5 degree): Temperature, geopotential height and wind at 12 isobaric levels, PPW, MSLP, OLR, Freezing level, lapse rate
- ERA-5 Reanalysis (0.25 deg): Divergence at all levels, Vertical Velocity, Vorticity, CAPE, Low, medium, high and total cloud cover, moisture convergence.

3. Analysis and Results

3.1 Annual and seasonal rainfall characteristics of NW Himalaya

Daily rainfall data of the three states (Uttarakhand, Himachal Pradesh and Jammu and Kashmir) are area-averaged in order to get Northwest Himalaya (NWH) daily rainfall data for the study period. The annual and seasonal (JJAS, OND, JF and MAM) rainfall are calculated from daily NWH rainfall data. The mean annual rainfall during 1951-2021 of NWH is 1267.1mm (±165.7) and monsoon rainfall 754.9mm (±131.1). During non-monsoon period, the mean rainfall during OND season is 98.2mm (±62.1), JF is 168.0mm (±60.3) and during MAM it is 246.1mm (±79.8). The spatial distribution of mean annual and seasonal rainfall across the NWH region shows large spatial variation across NWH states. The mean annual rainfall spatially varies from 713.4 to 2723.4 mm, JF rainfall from 55.2 to 320mm, MAM varies from 58.9 to 431.9mm, JJAS from 217.9 to 2164.5 mm and OND varies from 43.9 to 170.7 mm. The maximum annual rainfall spatially varies between 1281.4 to 4668.8 mm while that of JF: 155.4-2311 mm; MAM: 244.9-15.4mm; JJAS: 453.8-4090mm and OND: 240.3-1101.5mm (Fig 1)

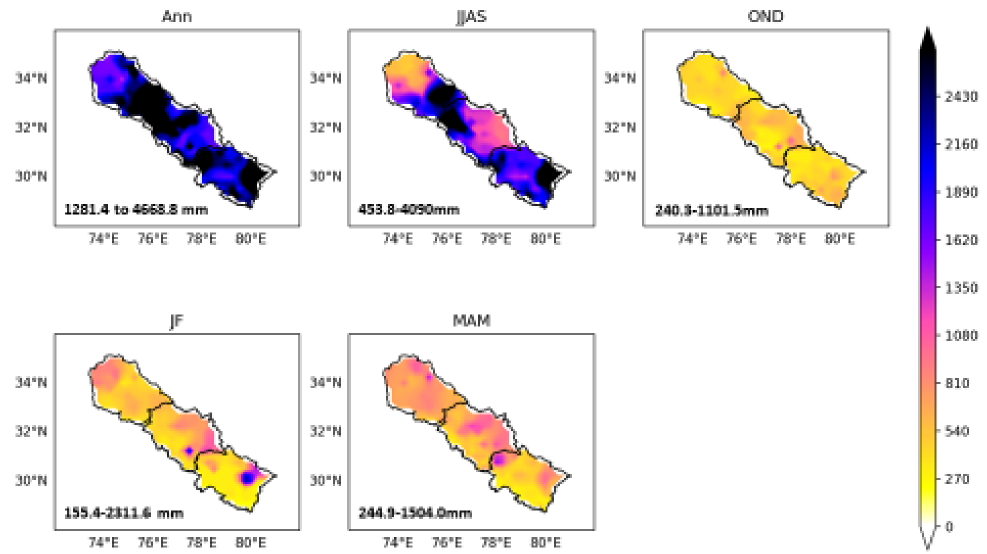


Fig1. Spatial distribution of annual and seasonal maximum rainfall during 1951-2021.

Inter-annual variations in area-averages annual and seasonal rainfall are studied using Mann-Kendall test for its trend detection. Visual examination as well as the statistical test does not show the existence of any long-term trend in NWH annual and seasonal rainfall during 1951-2021. However, in recent years (2001-2020) OND rainfall shows a significant decrease (-25.10%, significant at 5% level) compare to the preceding 51 years (1951-2000) record. JJAS rainfall shows 3.4% increase, JF: -2.9% decrease, MAM: -8% decrease and annual: -2.3% decrease in recent 20 years but all are not statistically significant.

3.2 Identification and characteristics of Large-scale Long-period EREs

The 1-to 10-day duration large-scale extreme rain events (EREs) are intended to quantify the severity of persisting intense rains over a particular area. In order to understand the variability of intensity of EREs of different durations, 1- to 10-day extreme rain events for each year during 1951-2021 concerning rainfall intensity and areal extent are identified over NWH. On daily basis each 0.25º sq grid is identified under wet condition if actual rainfall exceeds the daily mean monsoon rainfall (DMMR) of the particular grid. The DMMR is the daily mean rainfall during normal monsoon period over the grid. On the 0.25º grid scale, the DMMR varies between less than 2mm/day to more than 18mm/day across NWH. With DMMR as the threshold for the separation of wet grids, area averaged rainfall is calculated to identify large-scale long-period extremes.

The rainfall intensity (RI) of 1- to 10-day extreme is the annual maximum daily mean rainfall calculated for 1- to 10-day durations and the rainfall amount (RA) of 1- to 10-day extreme refers to annual maximum cumulative rainfall for the duration 1- to 10-days. The procedure has been applied for each year of the period 1951–2020 to get the sequence of extreme rain events concerning rainfall intensity (ERE-RI) for 1–day to 10-days durations. Based upon the number of grids under wet condition percentage area of NWH under wet condition is identified on daily scale. Extreme rain events concerning areal extent (ERE-AE) are identified as the annual maximum area under wet condition.

Climatological characteristics of 1- to 10-day large-scale extreme rain events concerning RI/RA and AE are given in table 1. Normally the mean RI decreases from 58.04mm (±20.77) per day for day-1 ERE to 25.93mm (±3.41) per day for 10-day EREs. While the rainfall amount increases form 58.04 mm (±20.77) to 259.28mm (±34.10) day for 1- to 10-day extremes respectively. The highest observed RI 1-day ERE was 146.51mm/day during 1968 and that of 10-day was 366.28mm/day during 1969. The areal extent of ERE-AE varies decreases from 17.3% for 1-day ERE-AE to 10.38% for 10-day ERE-AE. The standard deviation in the areal extent is about 1% for all EREs.

The distribution of cumulative rainfall intensity (highest observed, mean plus 2sd {standard deviation}, mean plus 1sd, mean minus 1sd, mean minus 2sd, mean minus 2sd. and lowest observed values; y-axis) for 1- to 25-day increases following a second-degree polynomial law with the duration (x-axis) (Fig2). The standard deviation (SD) which is the absolute major of variability increases linearly with the increase in mean maximum rainfall amount.

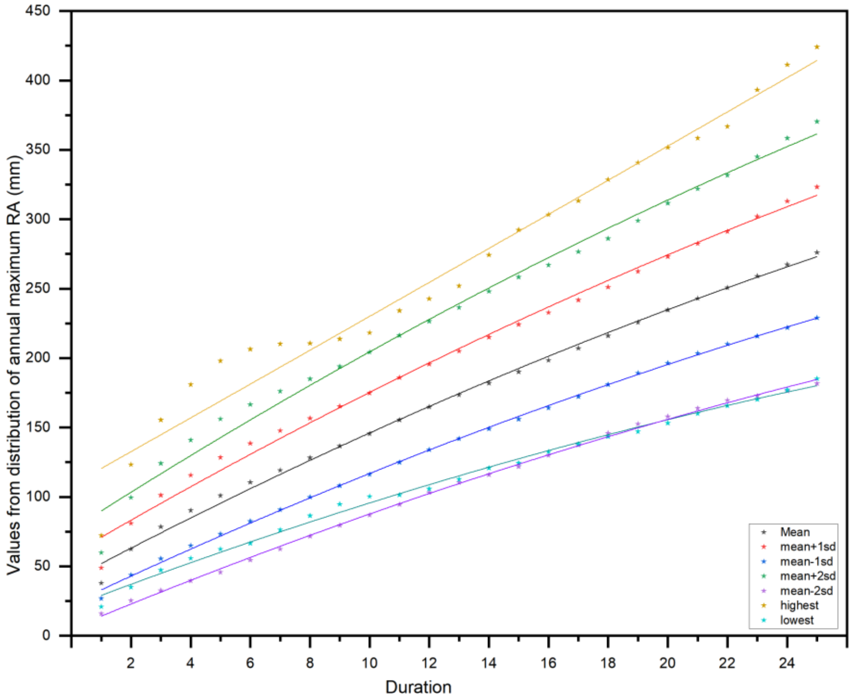


Fig2. Relationship between cumulative rainfall intensity and duration of 1- to 25-day Large-scale EREs

Inter-annual variations in rainfall intensity and areal extent of area-averaged 1- to 10-day EREs are studied using Mann-Kendall test. Results shows that, RA/RI of large-scale 1- to 5-ay ERE does not show any significant change tested using to Mann-Kendall test. Inter-annual variations of RA/RI of 1- to 10-day extremes are homogenous and random. In recent 20 years, RA/RI of 1-day ERE has been increased by 7.75% (statistically not significant) compare to preceding 51 years. No significant change is observed in RA/RI of 2-to 10-day ERE in recent 20 years. Areal Extent (%age) of large-scale 1-day ERE shows significant increasing trend (5% level) tested using to Mann-Kendall test. However, inter-annual variations of RA of 2- to 10-day extremes are homogenous and random. In recent 20 years, AE of 1-day ERE has been significantly (1% level) increased by 4.64% compare to preceding 51 years. No significant change is observed in RA/RI of more than 2- to 10-day ERE in recent 20 years.

3.3 Identification and characteristics of Isolated Spatio-temporal Long-period EREs

Small-scale isolated extreme rain events exhibit large inter-annual spatial variability. To understand characteristics of these extremes an elaborate analysis of temporal and spatial variability of 0.25 deg grid scale EREs of 1- to 10-day duration has been carried out. The annual maximum rainfall series on grid scale for one day has been prepared during 1951-2021 by selecting year-wise highest rainfall amount for a particular grid. Similarly annual maximum rainfall series for 2 to 10-day duration are also prepared.

The mean rainfall of 1-day ERE spatially varies from 50.3mm to 168.9mm across NWH states. For 10-day ERE, the RI (RA) varies from 12.1mm/day (121.23mm) to 52.8 mm/day (528.15mm). The spatial variation of highest experienced RI during the study period shows that, the 1-day ERE most extreme rainfall varies between 106mm and 762.9mm, while for 10-day most extreme ERE, the rainfall intensity varies between 26.3mm/day to 142.3mm/day. The highest rainfall amount of 10-day ERE observed to vary spatially from 263mm to 1422 mm. Most of the severe extreme rain events are observed to be occurred in Himachal Pradesh and Uttaranchal states (Fig3.)

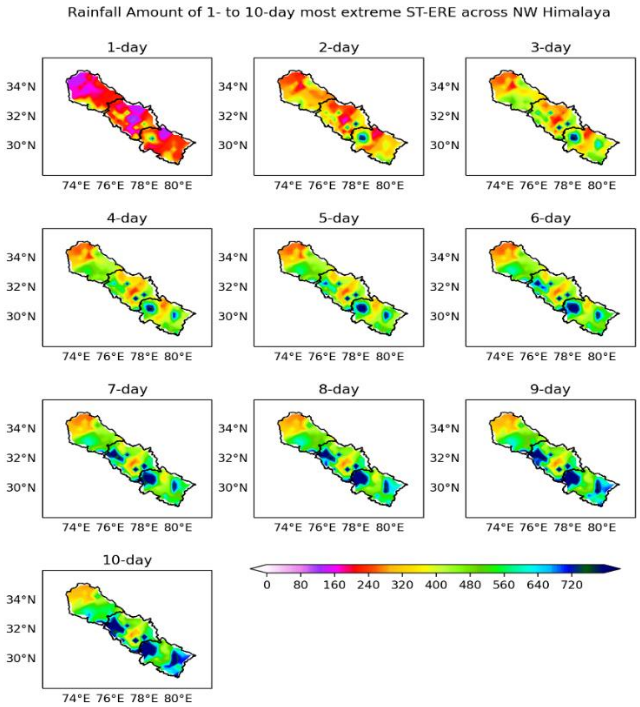


Fig.3 Spatial Distribution of Rainfall amount of the most extreme ST-ERE of 1- to 10-day duration during 1951-2021

3.4 Important Results:

1. The mean annual rainfall during 1951-2021 of NWH is 1267.1mm (±165.7) and monsoon rainfall 754.9mm (±131.1). No significant trend is observed is annual and monsoonal rainfall of NWH. The series are homogenous and random. However during recent 20 years (2002-2021), OND rainfall has decreased significantly by 25% compare to preceding 51 years (1951-2001).
2. Spatial distribution of annual maximum rainfall is highly variable. It varies between 1281.4 to 4668.8 mm while that of monsoon rainfall varies between 453.8-4090mm across the NWH states.
3. No significant long-term trend is observed in RA/RI of large-scale ERE-RI for 1 to 10-day duration EREs. However Areal Extent of large-scale 1-day ERE-AE shows statistically significant increasing trend.
4. In recent 20 years, RA/RI of 1-day ERE has been increased by 7.75% (statistically not significant), While AE of ERE-AE of 1-day duration has been increased significantly by 4.6% compare to preceding 51 years. No significant change is observed in RI/RA and AE of 2-to 10-day EREs in recent 20 years.
5. Increase in seven selected values from distribution of rainfall amount of 1- to 25-day EREs follow second-degree polynomial with increase in duration. The standard deviation which is the absolute major variability increases linearly with mean maximum rainfall amount.
6. The rainfall amount of 1-day isolated ST-ERE spatially varies from 50.3mm to 168.9mm. The cumulative rainfall of 10-day ST-ERE spatially varies from 121.2mm to 528.2 mm across NWH.
7. The highest experienced rainfall amount of 1-day isolated ST-ERE varies across NWH from 106mm and 762.9mm. The highest experienced RI of 10-day ST-ERE varies from 263.2mm to 1422.9mm
8. Most of the 1- to 3-day EREs are observed to be occurred below 3000m elevation across NWH states.

Deliverables

1. Provides in-depth information about the large-scale long-period and isolated spatio-temporal EREs. over the northwest Himalaya during different seasons of a year. T
2. Detailed understanding about the large-scale circulation dynamics, tropical-extratropical interaction mechanisms at different levels of the atmosphere, thermodynamical processes and the role of orography in the evolution and genesis of heavy rainstorms over Northern Himalaya.
3. The results are helpful for the assessment and prediction of the rainstorms over northwest Himalaya well in advance.

Adopters of the results of the study and their feedback: Weather analysist, water resources sectors

Major items of equipment procured: None

Lab facilities during the study: None

Specific linkages with Institutions/beneficiaries: None

Shortcomings/Difficulties: Shortage of manpower

ONGOING STUDIES (INTERNAL)

1. Title:

Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin

2. Project Team

NIH, Roorkee	DRC, Kakinada	WRD, Govt. of Andhra Pradesh
Dr. Sunil Gurrapu (**PI**), Sc. D Dr. Nitesh Patidar, Sc. C	Dr. Y R S Rao (**PI**), Sc. G & Head Dr. R Venkata Ramana, Sc. E	Mr. T V N A R Kumar Chief Engineer, Hydrology Water Resources Dept.

3. Type of Study: Internal

4. Status: Ongoing

5. Duration: 2 years

Date of Start: 1st April 2022

Scheduled Completion Date: 31st March 2024

6. Objectives

1. Analyse CMIP6 projected rainfall and temperature data for the state of Andhra Pradesh and generate multi-model scenarios of climate change.
2. Develop/calibrate and validate a hydrological model to simulate surface water and groundwater levels for the Pennar River Basin.
3. Generate hydrological scenarios (i.e. streamflow and groundwater levels) using CMIP6 projected climate.

7. Statement of Problem:

It has been globally accepted that the changing climate is imposing significant alterations in the hydrological systems, which eventually is leading to the changes in the characteristics of hydrological extremes. In a most recent special issue on the impacts of climate on hydrological extremes, the focus was on the historically observed hydrological extremes and how these extremes are linked to the changing climate in several watersheds across the globe. Therefore, to evaluate the impacts of changing climate on the basin hydrology and/or hydrological extremes, the knowledge of complex interactions between climate and hydrological systems is vital. In addition to the changing climate, the hydrological dynamics of a basin are affected by the changes in catchment characteristics and river flow regime, caused by the land-use/land-cover changes from anthropogenic activities. In brief, the on-going changes in the global climate and the anthropogenic effects on regional/local climate would trigger imbalance in the hydrological systems and eventually result in disproportionate changes in the hydrological extremes. Several studies from the recent past indicate that the hydrological extremes would be more frequent and widespread in future due to extreme weather events perceived to be induced by climate change. Therefore, information on the impacts of climate change on the basin's hydrology and the basin's hydrological projections of the 21st century becomes a vital information for water managers, irrigation engineers, city planners, hydro-electric engineers etc. The proposed project aims to analyse the projected rainfall and temperature data from CMIP6 GCMs and generate multi-model climate change scenarios for the state of Andhra Pradesh. The second major objective of the project is to generate hydrological scenarios using a calibrated and validated hydrological model and evaluate the impacts of climate change on the hydrology and extreme hydrology of a selected watershed. The generated hydrological scenarios and the results from impact assessment will benefit water managers, irrigation and hydro-electric engineers, to plan and allocate water appropriately for its effective use and reduce negative impacts of floods and droughts.

8. Progress:

The first objective of this study was to generate multi-model climate change scenarios for the state of Andhra Pradesh. To do so, the global climate scenarios derived from General Circulation Model (GCM) runs conducted under the coupled Model Intercomparison Project Phase 6, CMIP6 (Eyring we al., 2016) were to be used. The climate scenarios generated under CMIP6 were downscaled to a common grid of 0.25 degrees’ x 0.25 degrees (~ 25 km x 25 km) by NASA and is made available through NASA Earth Exchange Global Daily Downscaled Projections, NEX-GDDP-CMIP6 Trasher et al., 2022). These datasets were statistically downscaled using Bias-correction Spatial Disaggregation (BCSD) method. These datasets are available for a total of 35 GCMs for 4 SSP scenarios (i.e. SSP2-4.5, SSP5-8.5, SSP1-2.6, and SSP3-7.0) for the period 2015-2100, as well as the historical period 1950 – 2014. Of the existing 35 GCMs, 10 GCMs were selected based on the recommendations from the recently published climate change impact studies, and for 2 SSP scenarios, one likely (SSP2-4.5) and one unlikely (SSP3-7.0). These datasets were extracted and analyzed for the state of Andhra Pradesh and various change scenarios of precipitation and temperature were generated based on the multi-model statistics. In addition, to accomplish the second objective, a VIC model was developed for the Pennar River basin with a resolution of 5 km. Catchment characteristics for the basin were generated based on 30 m SRTM dataset, FAO soil map, and LULC information from Copernicus Global Land Service (CGLS). Meteorological information from IMD dataset at a resolution of 25 km x 25 km is used to run the model. For the calibration and validation of the model, daily averaged streamflow from selected streamflow gauging stations was collected from IndiaWRIS and also from various other gauging stations maintained and operated by the state Water Resources Department, Andhra Pradesh. The VIC model was run with the readily available preliminary data and the model fine-tuning is required. To simulate the groundwater levels in the basin, it is proposed to develop a model based on machine learning tools. Later, these models will be used to generate multi-model hydrological scenarios for the Pennar River Basin.

9. Deliverables

1. Multi-model climate change scenarios for the state of Andhra Pradesh.
2. Calibrated and validated hydrological model for the Pennar River basin, ready to be used in the future studies on the assessment of climate change impacts.
3. Multi-model hydrological scenarios generated for the Pennar River Basin, ready to be used by the officials of Water Resources Department, Andhra Pradesh to make decisions on effective management of available water.

ONGOING STUDIES (INTERNAL)

Title: Monitoring and Modelling of Gangotri (Bhojwasa) watershed under different Climate Scenarios

Project Team:

Dr P. K. Mishra, Scientist 'D'
Dr Vishal Singh, Scientist 'D'
Dr Sunil Gurrapu, Scientist 'D'
Dr Manohar Arora, Scientist 'F'
Dr Sanjay K Jain, Scientist 'G'
Mr. Jatin Malhotra, PRA

Project Duration: 03 Years (04/23 – 03/26)

Background and Objectives

The Gangotri Glacier (source of Bhagirathi River), one of the largest glacier of Himalaya, located in the Uttarakhand state (Central Himalaya, India) has immensely contributed to billions of people through irrigation, tourism, hydropower purposes (Singh & Jain, 2002; Kesarwani et al., 2015, Arora et al., 2016). Because of these reasons, hydrological studies in the Cryospehere regime of Himalaya has gained a massive momentum in recent times. Climate change and global warming has added more concern to the health of the Gangotri Glacier and the River Ganga as well (Singh et al., 2005; Arora et al., 2008 and 2010). It is, therefore, essential to study the hydrological system of the Gangotri Glacier System in a comprehensive way using observational methods, remote sensing based geospatial techniques and modelling so that prediction of future water supplies from these glacierized catchments in the downstream area can be performed precisely.

Department of Science and Technology (DST), in the year 1999, sanctioned a project to National Institute of Hydrology (NIH), Roorkee to carry out hydrological investigations on the Gangotri Glacier. Since then, many scientists and project staff from NIH has contributed immensely in carrying out the hydrological investigations through internal and external funding. To collect the information on the hydro-meteorological variables, NIH has established a standard observatory at about 3800 m altitude and set-up gauging sites at the basecamp at Bhojwasa. This observatory is equipped with Automatic Weather Station (AWS), ordinary and self-recording rain gauge, Thermograph, Max. & Min. thermometers, Dry & Wet bulb thermometers, Hydrograph, Pan evaporimeter, Anemometer, Wind vane, and Sunshine recorder. NIH is also carrying out the streamflow and sediment contribution through traditional approach. The installed AWS and Prefabricated Hut is quite old and require alteration, renovation and repairing. The site requires upgradation and adoption of new modern techniques for flow and sediment measurement.

To continue the long legacy of data monitoring and hydrological investigations of the Gangotri Glacier, the present study has been proposed with the following objectives:

- To conduct continuous observations of meteorological, hydrological and suspended sediment data to determine monthly and seasonal flow and sediment yield for the melt season.
- To carry out the seasonal characterization of the glacier melt.
- To estimate the suspended sediment yield from the Glacier.
- To set-up different hydrological model(s) for runoff estimation under different climatic scenarios.

Methodology

Study area:

The study will be conducted for the Gangotri Glacier up to the basecamp at Bhojwasa at an altitude of 3800 m. The Gangotri Glacier is a cluster of many glaciers comprising of main Gangotri Glacier (length: 30.20 km; width: 0.20 – 2.35 km; area: 86.32 km^2) as trunk part of the system. The Gangotri Glacier is a valley type glacier system with total glacierized area of about 286 km^2. Total catchment area of the Gangotri Glacier and melt stream up to the discharge-gauging site established downstream at Bhojwasa is about 556 km^2. The elevation range of the Gangotri Glacier varies from 4000 to 7000 m, whereas elevation of the study area up to the gauging site lies between 3800-7000 m.

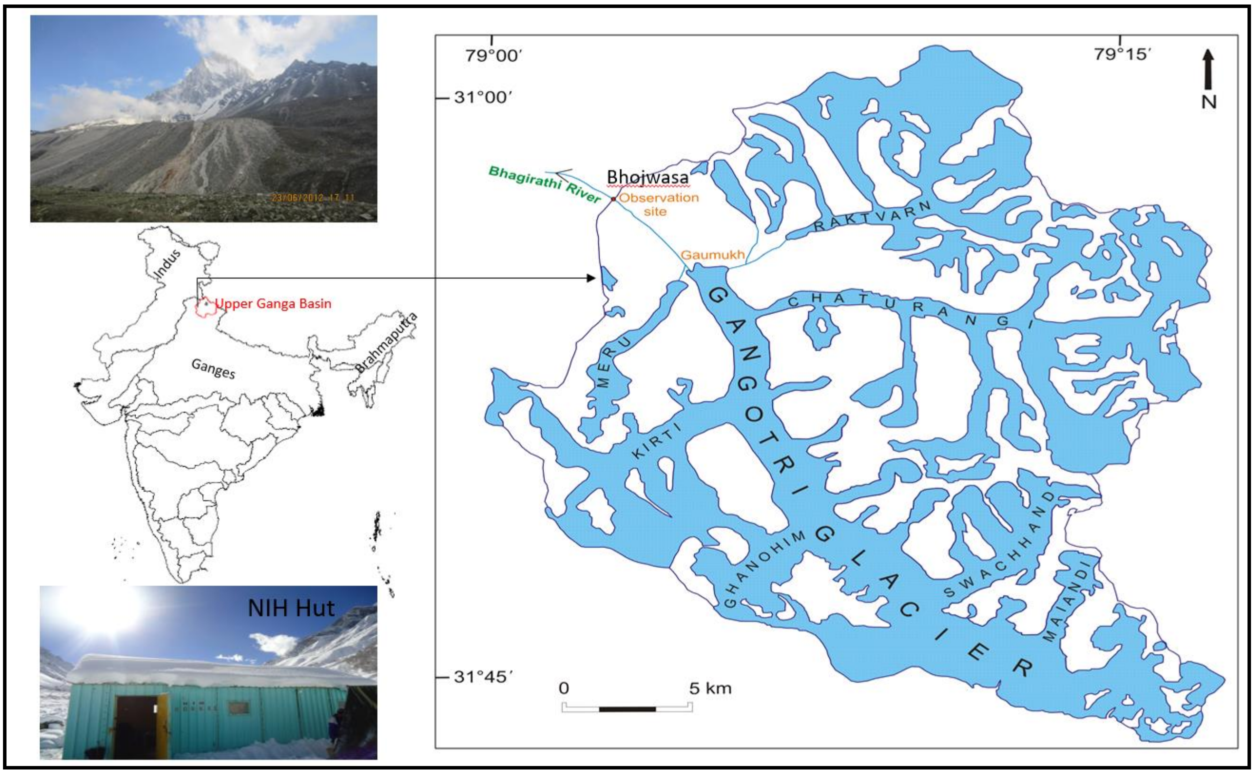


Fig. 1 Location Map of the Gangotri Glacier System

Research Approach:

A few activities/tasks have been defined to accomplish the study's research objectives such as conducting field visits during the ablation period (May-October), regular up-keeping and monitoring of equipments, collection of data, analysis of collected data, model setup, scenario-based analysis, etc. The task-wise brief methodology proposed is indicated below:

Task 1: Before conducting the field visit(s) for the ablation period (May-October)

- Obtaining permission from the Gangotri National Park, Uttarkashi
- Deployment of manpower
- Procurement and arrangement of logistics, insurance, chart papers, bottle and other accessories
- Calibration of equipments
- Actual field visit(s)

Task 2: During the field visit(s) for the ablation period (May-October)

- Cleaning of the Hut and Observatory site like fixing the fences, etc.
- Setting-up the Sunshine recorder, hydrograph, thermograph, tipping bucket rain gauge, ordinary rain gauge, wind vane, evaporimeter, etc.
- Identification of site and installation of staff gauge
- Measurement of (Rough estimate) stream cross-section
- Retrieving the data from the AWS

- Regular monitoring and keeping record of hydro-meteorological data and sediment sampling
- Winding-off the equipments and Closing-off the site

Task 3: After the field visit(s) during non-ablation period (November-April)

- Data entry, collation, compilation and analysis
- Hydrological modeling (HBV; SPHY; VIC)
- Analysis of sediment data
- Summarizing major findings and Report preparation
- Preparation of adaptation/management strategies/plans

7. Research Outcome from the project:

- Long-term Meteorological and hydrological data for the Gangotri Glacier
- Characteristics of the Gangotri Glacier under changing climate

8. Action Plan

Year	May to October	November to April	Remark
All Years	Field investigations & Data Collection	Data analysis	Interim & Final Report preparation

9. Cost estimates:

The total cost of the project: **₹ 57 Lakhs**

a. Source of funding: NIH
b. Sub-head wise abstract of the cost:

SN	Sub-head		Amount (₹)		
		Year - I	Year - II	Year - III	Total
1	Procurement of i. Discharge Monitoring Station ii. Sediment Sampler iii. Data logger (AWS) iv. GPS	30,00,000	-	-	30,00,000
2	Salary (Part-Time Field Staff)	4,50,000	4,50,000	4,50,000	13,50,000
3	Field visit (May-Oct.) (Refilling of cylinder; Insurance; Porter; Entry fee; Forms; Stationery; Filter paper; Bottles; Charts; Staff Gauge, Wooden blocks, and other Misc. items	3,00,000	3,00,000	3,00,000	9,00,000
4	Workshop/ Meeting/ Experimental Charges	-	-	1,50,000	1,50,000
5	Misc. expenditure (Contingency)	1,00,000	1,00,000	1,00,000	3,00,000
	Sub- Total:	38,50,000	8,50,000	10,00,000	57,00,000
	Grand Total:		**57,00,000**		

ONGOING STUDIES (INTERNAL)

1. Title: Glacier recurrence survey, Instrumentation and Modeling to study the Batal Glacier in part of Western Himalaya, India

2. Project Team:

Dr. Vishal Singh, Sc. D & PI
Dr. P. K. Mishra, Sc. D & Co-PI
Dr. Sunil Gurappu, Sc. D & Co-PI
Dr. Sanjay K. Jain, Sc. G (Head-WRSD) and Co-PI
Dr. Manohar Arora, Sc. F and Co-PI
Mr. Jatin Malhotra, PRA

3. Summary

This study has been proposed to carry out a research analysis over the Himalayan glaciers to assess the impact of glacier retreat and climate change in the long-term time frame (e.g. 21st century). The main purpose of this study is to explore the understanding of glacier-climate-topographic inter-relationship and quantify the Himalayan glacier responses to the river runoff, which is originated from the glaciers. For this purpose, initially, a glacier survey will be conducted to identify a new glacier focusing on Indus basin part of the Western Himalayan regions (e.g. Batal glacier-tentatively identified which is a part of Chandra Basin and other nearly situated glaciers). Based on the recurrence survey, a feasibility report will be prepared as per the Glaciers cryospheric, topographical and climatological characteristics. After the recurrence survey, a research observatory will be established near to the glacier for the long-term monitoring of various glacier and hydro-meteorological parameters.

The observatory will be equipped with scientific instruments such as Automatic Weather Station, Water Level Recorder, Soil Moisture Sensors. Sediment Samplers, Snow Gauge (Depth and Sensitivity) etc. The measured datasets will be utilized for the real time study of glacier changes and downstream based hydrological assessment. The second most important objective is to develop a real time modelling framework to compute the river runoff, sediment yield and other watershed components utilizing the hydrological models viz. SPHY/SWAT/VIC. In this study, the glacier retreating and mass changes through mass balance analysis will be performed utilizing the observation and satellite remote sensing datasets. Different glacier sizes may behave differently under different altitudes and topographical conditions and thus the timing and amount of resultant runoff may be varied. These aspects are still need to address in the Himalayan river basins under glacier retreat conditions. The analysis of interactions between precipitation, temperature, surface albedo, evapotranspiration (ET) and soil moisture at different altitudes in the proposed Himalayan river basins can be important to assess the magnitude of glacier retreats and changes in runoff components in terms of glacier melt, snow melt, baseflow and rainfall induced runoff.

3. Objectives

Following objectives have been defined under the current proposed:

- To conduct a glacier survey through physical verification and collect field observations by preparing the feasibility report as per the identified glacier (or group of glaciers) and also to setup the new glacier observatory for the long-term monitoring of glaciers.
- Instrumentation in the glacier site for the measurement of real time glacier and hydro-meteorological parameters.
- Development of an improved modelling framework to address glacier changes and its impact on river runoff.
- Glacier mass balance and seasonal characterization of glacier parameters.

4. Present state-of-art

A glacier survey in a physical model will be conducted to identify the most suitable glaciers for the analysis of glacier changes and its impact on river runoff and other watershed components. A feasibility report will be prepared as per the survey and the cryospheric, topographical and hydro-climatological characteristics of the glacier will be comprised. Then the instrumentation will be done in the glacier site for the analysis of different glacier parameters in the real time domain. The scientific instruments such as Automatic Weather Station, Water Level Recorder, Soil Moisture Sensors. Sediment Samplers, Snow Gauge (Depth and Sensitivity) will be procured and established for the measurements of glaciers. For glacio-hydrological analysis, the modeling based framework will be developed utilizing the widely used modeling tools such as SPHY, SWAT and VIC etc. However, as the Himalayan glaciers are unique in nature and thus some modifications will be done by incorporating the effect of local parameters mainly to enhance the accuracy of the computed outcomes. Model calibration and validation will be done utilizing real time remote sensing data products and observed hydro-observational datasets. The snow and glacier melt runoff contribution in total discharge will be accounted and their fluctuations will be analyzed. The comparative seasonal and monthly snow cover and glacier change (area/volume/thickness) will be computed to highlight the variability in the glacier mass and other parameters. The mass balance of selected glacier will be done as mass balance methods as utilized previously utilizing the remote sensing, and field observation datasets. The effect of slope, aspect and elevations will also be incorporated to analyze their effects on glacial retreating and resultant runoffAs per the seasonal changes in precipitation and temperature at different altitudes within the glacier body and its catchment area will be studied and their relation to evapotranspiration (ET), soil moisture, surface temperature, radiation and surface albedo will be explored. Surface albedo and radiation have been recognized as important drivers to affect the snow cover and snow water equivalent. The snowpack cold content and albedo decrease when the intensity of shortwave radiation and temperature increases.

5. Deliverables

- Feasibility of report on the glacier status in the western Himalayan region.
- Establishment of observatory and instrumentation for the real time monitoring and measurement of the snow and glacier parameters.
- Glacier mass-balance and other glacier parameters database.
- Real time information of glacier induced river flow and other watershed components in the form of digital database and maps.
- Conclusive remarks on glacier mass balance changes (in terms of area, thickness and volume).

6. Relevance to Centre for Cryosphere and Climate Change Activities

The above proposed study is a major objective of newly established Centre for Cryosphere and Climate Change at NIH Roorkee.

7. Duration of the project – 5 years (Apr. 23 – Mar. 28)

7.1 Stage of work and milestone:

Stage of Works	Year 1		Year 2		Year 3		Year 4		Year 5	
	6m	6m	6m	6m	6m	6m	6m	6m	6m	6m
A. Glacier Survey & Feasibility Report										
B. Instrumentation & Field Works (Procurement & Installation)										
C. Evaluation of Parameters, Database Organization& Data Pre-processing										
D. Development of Modeling Framework										
E. Modeling: Simulation and Analysis										
F. Modeling: Simulation and Analysis & Final report writing and research paper publications										

8. Budget: Rupees - Seventy One Lacs Only (Rs. 71,00000/-)

SI. No.	Name of Activity	Y1	Y2	Y3	Y4	Y5	Total Rs (in Lacs)
1	Salaries and wages: (1 Resource Person- Junior/Senior)	5.00	5.00	5.00	5.00	5.00	25.00
2	Consumable materials: (Satellite Data/Other datasets)	5.00	1.00	1.00	-	-	7.00
3	Travel and field expenses: (Recurrence Surveys & Field Works)	3.00	2.00	2.00	2.00	1.00	10.00
4	Instruments: (AWS, Snow Gauge, Snow Depth, Snow Density Gauge, Water Level Recorder)	20.00	-	-	-	-	20.00
5	Other items and Contingencies	1.00	1.00	1.00	0.5	0.5	4.00
6	Non-recurring expenses	2.50	2.50	-	-	-	5.00
7	**Total Rs. (in Lacs)**	**36.5**	**11.5**	**9.0**	**7.5**	**6.5**	**71.00**

ONGOING STUDIES (SPONSORED)

1. Title - Snow and glacier contribution and impact of climate change in Teesta basin in Eastern Himalaya

2. Study Team

NIH Roorkee:

Dr. Sanjay K Jain, Scientist 'G'
Dr. P K Singh, Scientist 'D'
Dr. Manohar Arora, Scientist 'F'
Dr. A K Lohani, Scientist 'G'
Dr. Vishal Singh, Scientist 'D'

JNU, New Delhi:

Dr. A P Dimri, Professor

CAU Sikkim:

Dr. S R Yadav, Assistant Professor (SWCE)

IITM Pune

Dr. (Mrs) Nayana Deshpande, Scientist D

3. Objectives

The proposed project will adopt an inter-disciplinary approach to address the following objectives, in particular for the Teesta basin within the eastern Himalayas:
The objectives of this study are:

- Assessment of recent changes in snow, glacier, rainfall and its impact on the hydrology of the Teesta basin through Hydrologic modelling.
- To understand the influence of glacier size, debris cover, topographic (i.e., altitude, aspect, and slope) and climatic variables on recent glacier changes?
- Sediment transfer characteristics of Teesta River at selected sites and identification of major drivers.
- Assessing climate change in the basin and future scenarios and resultant hydrological responses
- To understand and simulate the magnitude of the GLOF hazard of glacial lakes formed due to glacier recession using MIKE-II breach modeling.
- Identification of key change indicators for water resources of the region and their impact on local communities
- To develop a comprehensive and interactive web-enabled database repository of the hydro-met database and modelling spatial outputs with basic GIS functionalities.

4. Sponsored by NMHS, MOEF & CC

5. Project Cost Rs. 143 Lakhs

6. Methodology

In the present study, modelling of snow/glacier melt runoff, sediment sampling and modelling, climate change studies, impact of climate change and glacier lake outburst flood are proposed to achieve the objectives.

- Snow/glacier melt runoff modelling will be done using SNOWMOD and VIC models. Landuse/landcover, snow/glacier maps etc. will be prepared for the study basin using standard RS and GIS techniques. Hydro-meteorological data will be collected from different sources such as CWC, IMD, NHPC and state agencies.
- Sediment yield modelling and assessment will be done using Delivery Ratio and GIS coupled empirical models, SWAT model and conceptual SCS-CN based sediment yield models.
- Many methods have been developed for generating climate scenarios for the assessment of hydrologic impacts of climate change, which include downscaled general circulation model

(GCM) simulations. Data and knowledge generated will be used to implement a sub-grid scale parameter scheme for Regional Climate Model using RegCM4 model with sub-grid parameterization and refined future projections for climatic variables.

- The satellite data along with field investigations will be used to assess glaciers and glacial lakes. MIKE 11 model will be used for GLOF simulations.
- A comprehensive web enabled database repository will be developed based on information from the field data collection and modelling results.

7. Time-Line and Activities

	Activities	**1^{st} Year**		**2^{nd} Year**		**3^{rd} year**	
NIH	Hiring Manpower	■					
	Procurement of the instruments	■	■				
	Data collection and database preparation		■	■	■		
	Model data need and requirement by other PIs			■	■	■	
	Model simulations and sensitivity analysis			■	■	■	
	Study of impact of climate change			■	■	■	
	Sediment studies				■	■	
	GLOF studies			■	■	■	■
	Development of a comprehensive and interactive web-enabled database repository			■	■	■	■
	Workshops/Trainings				■	■	■
	Report writing					■	■
CAU	Hiring Manpower	■					
	Procurement &installation of Met. stations	■	■	■			
	Data collection and Data synthesis		■	■	■	■	
	Sediment studies			■	■	■	■
	Report writing						
JNU & IITM	Hiring of manpower	■					
	Climate modelling work		■	■	■	■	
	Report writing					■	■

8. Progress till-the-Date

Spatial Process in Hydrology (SPHY) model has been used for the overall water balance computation and then the separation of all main runoff (Q) components (e.g. snow melt runoff, glacier melt runoff, base flow and rain induced runoff) for Teesta river basin. However, the main emphasis is given to the glacier melt and snowmelt runoff computations. In the upstream point at Chungthang, the contributions from different runoff components are recorded as 47% from rain induced runoff, 25% from glacier melt runoff, 23% from snowmelt runoff and 5% from baseflow. At outlet (Teesta lower dam IV), the contributions from different runoff components are recorded as 78% from rain induced runoff, 10% from glacier melt runoff, 9% from snowmelt runoff and 3% from baseflow. We also applied SWAT model and found that the snow and glacier melt runoff contributes about 16% to the average annual flow of the Teesta lower dam IV of the Teesta river basin. Soil erosion modelling using RUSLE shows that the area under extremely severe erosion category in Teesta basin is 38.17%, 39.52% and 41.81%, respectively due to CHIRPS, IMDAA and TRMM datasets. Similarly, the area under very severe erosion is found to be 8.18%, 7.81% and 9.23% and under severe erosion as 11.62%, 10.91% and 11.17%, respectively due to CHIRPS, IMDAA and TRMM datasets. Finally, the future assessment of the soil erosion has been done by using the best performing CMIP6 models for the study region, i.e., EC-Earth3 and BCC-CSM2-MR for two Shared Socioeconomic Pathways (SSPs), i.e., SSP245 and SSP585 for Near Future (2021-2050), Mid Future (2051-2080) and Far

Future (2081-2100). The results show that there is an increase in the percent (%) area susceptible under extremely severe erosion in Near Future, Mid Future and Far Future under EC-Earth3 (~64%) and BCC-CSM2-MR (~48%) models with respect to SSP245 and SSP585 projection scenarios as compared to the historical period (2000-2019). The glacial lake inventory was done for the years 1990, 2000, 2010, and 2020 and we found 25 most vulnerable lakes (based on several weighted geometric and geomorphic characteristics), out of which 10 lakes are with the highest GLOF threats. These lakes are largely located near the major snowline and great Himalayan water divide in Sikkim's north-eastern region. Keeping in view these findings, these lakes should be monitored on a regular basis.

ONGOING STUDIES (SPONSORED)

1. Project Title: Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram.

2.	**Duration of the project** :	**3 years (04/21-03/24)**
3.	**PI and Co-PI from Lead Organization** :	PI: Dr. Vishal Singh, Scientist- D Co-PI: Dr. M.K. Nema, Scientist- D Dr. P. K. Singh, Scientist- D
4.	**Investigators from Partner Organization** :	1. Mr. K. Hamlet, Sr.EE 2. Mr. Vanlalpekhlua Sailo, AE

5. Objective of the Study

The major objective of this study is to apply the advance modeling framework for Barak, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA) sub-basins in the state of Mizoram for water security plan. This will generate useful base data to help development of proper water management strategies and decision processes. The major objectives of the study area as follows:

a. To collect, prepare and evaluate various thematic datasets such as digital elevation model, land use/Land cover (LULC) map, soil map, population data (census) and hydro-meteorological data-sets such as precipitation, temperature, discharge etc.
b. Long-term Rainfall trend analysis based on rainfall frequencies and intensities to analyse the effect of climate change as per the standard guidelines.
c. Hydrological modelling, calibration and parameterization over Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar subbasins in the state of Mizoram for the assessment of watershed components (including surface and groundwater) and water availability using SWAT and SWATCUP models (Arnold et al., 2012).
d. Analyzing the effect of LULC changes on the hydrological scenarios such as water availability (or water yield) at sub-catchments scale and discharge at the outlets.
e. Analyzing the effect of climate changes on the hydrological systems, with possible thresholds for resilience under different conditions and combinations anticipated.
f. To setup WEAP model (Levite et al., 2003) for calculating water demand of Mizoram state subject to mid-term water availability (say up to 2050) to increase water use efficiency and maintaining the adequate water supply sustainable development.
g. To prepare the detailed report for study basins/sub-basins in Mizoram state as per the mid-term hydrological assessment with the guidelines of water security plan with particular reference to demand points (domestic, irrigation or others) identified by the Water Resources Department, Government of Mizoram.
h. To impart training on "hydrological modelling" to the state officials of Water Resources, Agricultural and other related Depts, as well as officers from other implementing agencies of the National Hydrology Project.
i. Selection of dam sites with suggested capacity to meet the growing demand of water in the state.

6. Study area

Mizoram, with an area of 21,087 km^2 is largely divided into three major river basins: one is the Barak basin (8,935 km^2) in the central to northern part of the state, the second is Kolodyne basin (8,144 km^2) in the southeastern part, and the third is Karnaphuli basin (3,999 km^2) in the southwestern part, as shown in Figure 1.

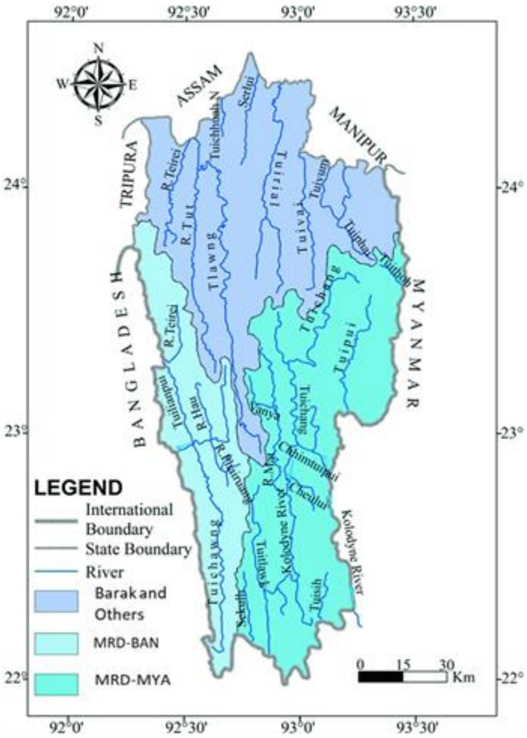


Figure 1: River basin map of the Mizoram showing river basins namely Barak and Other, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA).

7. Brief Methodology

7.1 Processing of meteorological datasets

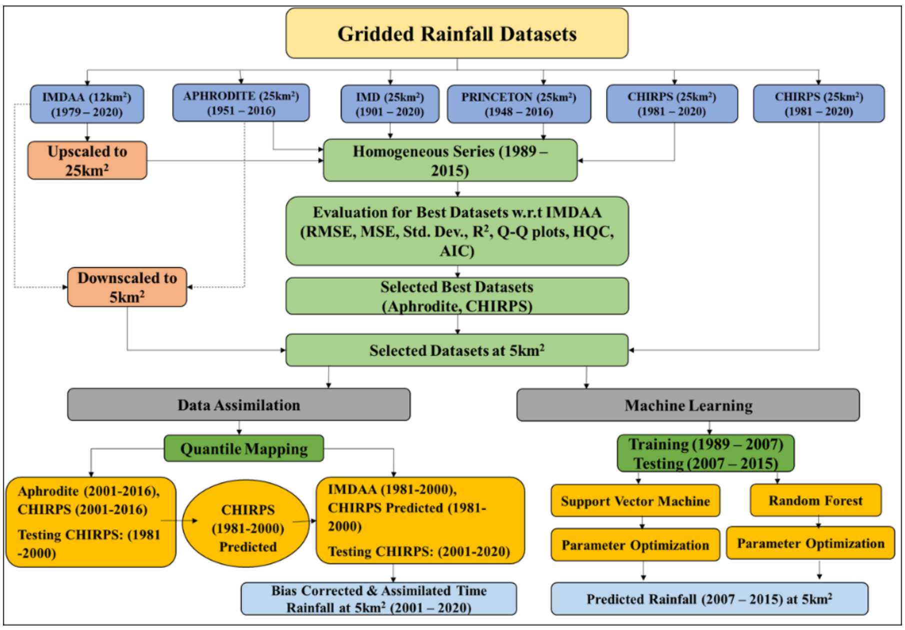


Figure 2: Processing of meteorological datasets and generation of new hybrid gridded rainfall.

7.2 Climate projections and rainfall indices

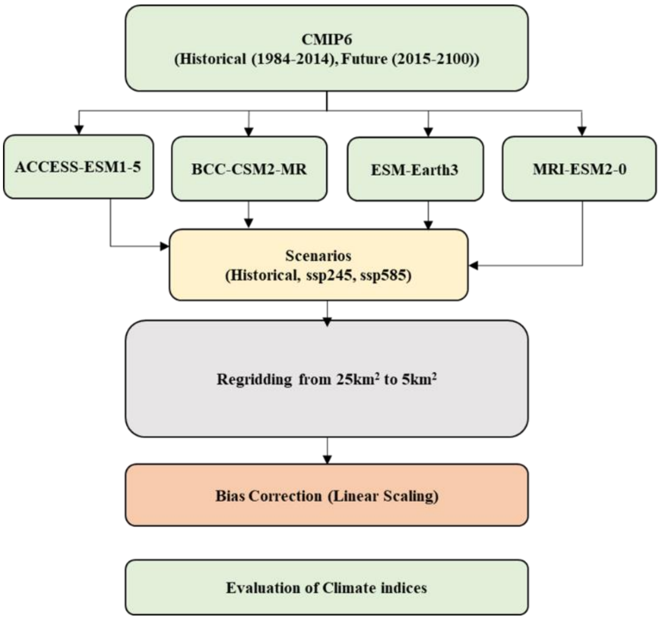


Figure 3: Analysis of rainfall indices to analyse changes in rainfall.

7.3 Overall modeling methodology

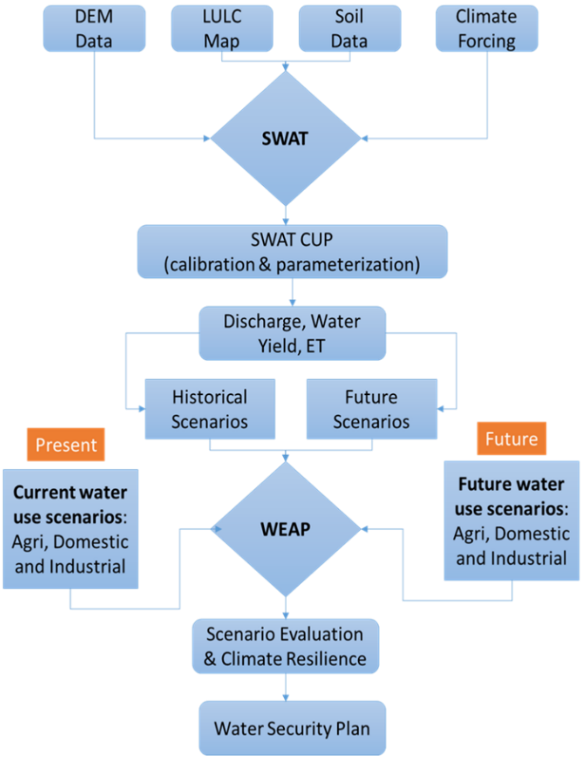


Figure 4: Overall modeling methods.

8. Expected Deliverables

- A detailed outcome of water balance components including surface and groundwater.
- Rainfall extreme trends discharge scenarios (up to 2050), with possible plans and thresholds for resilience with and without structural interventions under the anticipated conditions and combinations thereof.

- Basin/sub-basin wise water availability: Supply-Demand and Consumptions and Water Availability, considering a development period of 5 years and a planning horizon of 30 years.
- LULC change maps, soil maps and river networks.
- Guidelines and schema of water security plan, with particular reference to identified locations with significant demand. Planned developments will be taken into consideration.
- Report and Recommendations of best practices suitable for the catchments
- Trainings on hydrological models to the officers from Mizoram IWRD and other Implementing Agencies of the NHP.

9. Expected Timeline against the Deliverables

Project Year	**Mar 2021-Feb 2022**		**Mar 2022-Feb 2023**		**Mar 2022-Aug 2024**	
Project Quarter	**M 1-6**	**M 7-12**	**M 13-18**	**M 19-24**	**M 25-30**	
a. Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments						
b. Data analysis, Trend generation, SWAT setup						
c. Hydrological Assessment & Calibration						
d. Projected Scenarios using GCMs and Climate Resilience Analysis						
e. WEAP setup and water availability and demand assessment						
f. Report and Recommendations of best practices suitable for the catchments						
g. Training modules on Hydrological Model						

10. Progress till date

Sl No.	All Planned Activity as per original work plan in approved PDS	Cumulative % Progress in the activity in this quarter	Comments / details of activities
1	Hiring Manpower: JRF	100%	The JRF has been recruited.
2	Nomination of Nodal-cum-Liasioning Officer from WRD Nagaland	100%	Chief Engineer cum Nodal Officer (NHP), WRD Nagaland has been approached to nominate a Nodal-cum-Liasioning Officer for smooth conduct of the study. SE K. Hamlet and AE Vanlalpekhlua Sailo have been nominated for the same.
3	Collection and Processing of Thematic and Meteorological Datasets	100%	Done. A new Gridded Hybrid Rainfall datasets have been generated.
4	Quality Check and Bias Correction of Hydro-meteorological datasets	100%	Done
5	Development of SWAT model	90%	Model setup has been done. Model improvements, Calibration and Validation have been done and all watershed components have been generated

6	Calibration and Validation	60%	A manual calibration has been done at 4 gauges as per the available observed Q
7	Processing of Climate Model datasets	100%	For this study, the latest climate model datasets by Coupled Modelled Inter-comparison Projects (CMIP) under World Climate Research Programme (WCRP) named Coupled Modelled Inter-comparison Project Phase 6 (CMIP6) have been utilized. Initially 13 models, and each model includes five scenarios (historical, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) were taken. After the Uncertainty Assessment of the Climate Models w.r.t. Observed Rainfall, four climate models viz. ACCESS ESM 1-5; BCC-CSM2-MR; EC-Earth3 and MRI-ESM2-0 considering three scenarios each (e.g. historical, SSP2-4.5, SSP5-8.5) have been selected for the final analysis. Bias correction of the selected model was done using Quantile Mapping method.
8	Rainfall analysis	100%	For this purpose, the bias corrected climate model datasets were divided into two terms viz. near term (2020-2050) and far term (2060-2090) and for each category annual average and climate indices were calculated as per the guidelines of IPCC. Climate indices considered here are: Dry days: if rainfall is <2.5 mm/day Wet days: if rainfall is >2.5 mm/day Dry spell frequency: if rainfall is <2.5mm/day for a continuous 5 days Wet spell frequency: if rainfall is >2.5mm/day for a continuous 5 days Maximum 1-day precipitation per year (Rx1D): maximum precipitation in a day WDx95: Number of wet days with daily precipitation over a 95 percentile
9	LULC Change Analysis	75%	Predicted LULC maps have been developed and their effects on hydrology has been analyzed
10	Water Availability and Demand	25%	The data inputs are prepared and the model setup is due.

ONGOING STUDIES (SPONSORED)

7. Title: Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya

8. Project Team:

Dr. Sanjay K. Jain, Scientist 'G'
Dr Manish Kumar Nema, Scientist 'D'
Dr P. K. Mishra, Scientist 'D'
Dr. Praveen Thakur (IIRS)

9. Project Duration: 03 Years (04/22 – 03/25)

10.Scope of the Work

The scope of the work to be carried out in the project includes:

a. Characterizing spatial extent and patterns of hydrological cycle components in selected watersheds in Western Himalaya (Uttarakhand) using multi-scale EO data;
b. Assessment of watershed's topographical, morphological and hydro-meteorological spatio-temporal dynamics using a systematic and multi-site sampling using ground observations and EO inputs;
c. Determining the EO-based land surface parameters and hydrological cycle variables of the watersheds and its dynamics;
d. Developing hydrological models for multi-scale assessment of hydrological cycle components and water availability linking natural hydrological processes and anthropogenic water use under present and future climate scenarios;
h. Developing a web-based hydrological information system, supporting hydrological and spatial database, web analytics and data/information dissemination for water resources planning and management.

11. Deliverables

- Establishment of long term, experimental watershed monitoring sites with field instrumentation for understanding various hydrological and snow/glacier processes which are important in overall water balance studies.
- The updated geospatial-database on hydrological sources and water resources of the selected watersheds.
- Quantification of hydrological response of the selected watersheds and assessment of basin level water availability in the Upper Ganga Basin of NWH region under present and future climate change scenarios.

12.Cost estimates:

The total cost of the project: **₹ 30.91 Lakh**

c. Source of funding: IIRS
d. Sub-head wise abstract of the cost:

Head	Total grant (Lakh)
Recurring	
(i) Salary + HRA: 01 JRF or Project Fellow	**10.88**
(ii) Field work and Travel (Domestic)	**6.5**

(iii) Services (Field activities & other project costs: Field sampling for hydrological data collection and lab analysis of soil/water samples; contingency/consumables, skilled/non-skilled labor hiring for watersheds data collection), data, printing of project report/outputs and other charges.	**9.5**
(vi) Institutional charges/ Overhead	**4.03**
Grand Total*	**30.91***

Say **Rupees Thirty Lakh Ninety-One Thousand and Two Hundred only** from IIRS. *This is the maximum amount, which can be transferred during project duration. Actual budget transfer to be as per actual funds availability from ISRO, progress of work and utilization of given funds by the collaborating institute.

8. Project Schedule

Duration of project shall be **Three (03)** years from the date the project has been sanctioned by ISRO and approval of budgetary provisions.

Activity	**Year I**	**Year II**	**Year III**
Project initiation, Inception workshop			
Recruitment of project personnel			
Permission for field studies			
Workshop for field training			
Field instrumentation/sampling			
Acquisition of Satellite based Earth Observation data			
Progress review/workshop			
Hydrological data collection, development of web based data repository and information system			
Development of hydrological models for multi-scale water resources availability			
Generation of spatial layers on hydrological fluxes for present and future climate scenarios			
Progress review and stakeholder workshop			
Final Report generation			

9. Progress till date:

- A workshop (online) was conducted to sensitize the project partners regarding the project outlines and deliverables by IIRS.
- A JRF has been recruited as provisioned in the project
- A Two-day training and exposure Programme was organized for all the SRFs/JRFs during 19-23 December, 2022 at IIRS, Dehradun.

A joint field visit was conducted by NIH, Roorkee and IIRS, Dehradun to identify suitable sites for installation of AWS and equipments under the non-glaciated watershed component.

ONGOING STUDIES (SPONSORED)

1. Title of the Project

Development of Water Accounts for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland using Water Accounting Plus (WA+) Framework.

2. Project Team:

Dr P. K. Mishra, Scientist 'D'
Dr P. K. Singh, Scientist 'D'

3. Project Duration: 02 Years (04/21 – 06/23)

4. Objective of the Study

The major objective of this study is to apply the newly developed WA+ framework for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland for estimating the status of the water resources. This will generate useful base data to help development of proper water management strategies and decision processes. The specific objectives are:

1. To set-up WA+ Framework for the selected study basins/sub-basins.
2. To estimate ET consumption patterns for the selected basins/sub-basins.
3. To estimate land and water productivity for the selected basins/sub-basins.
4. To develop Resource Base (Surface water & Groundwater) for the selected basins/sub-basins.
5. To develop capacity on WA+ to the State Govt. officials from WRD, Nagaland through training programmes

5. Scope of the Study:

The scope of this study is as follows:

a. To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
b. To develop accounts for agricultural services (i.e., land productivity and water productivity).
c. To collect hydrological and meteorological data.
d. To collect data on topography, soils, river networks, drainage networks and land-use & land-cover.
e. To validate, analyze and process the data collected and give necessary inputs.
f. To develop water accounts for the study basins/sub-basins.
g. To prepare the detailed WA+ report for study basins/sub-basins.
h. To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

6. Study Area and Input Data

The state of Nagaland is a north eastern state of India and is surrounded by the states of Assam, Manipur, Arunachal Pradesh and also by Myanmar in the East. The state covers a geographical area of approximately 16580 km^2. The major part of the State is drained by the Brahmaputra basin (~10881 km^2, 65.6%) followed by Barak basin (~814 km^2, 4.9%) and by Irrawady-Chindwin basin (~4884 km^2, 29.5%). The state of Nagaland is divided into three river basins viz, rivers flowing to Brahmaputra, rivers flowing to Barak and the rivers flowing to the Irrawady-Chindwin basin.

Input Data

The WA+ framework focuses on the use of open source and remote sensing satellite datasets in an effort to maintain a high level of transparency and applicability in ungauged basins. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and many other agencies are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study. Data sources are given in Appendix 1**.**

- Precipitation: Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)/ Tropical Rainfall Measuring Mission (TRMM) [now available as Global Precipitation Measurement (GPM)]
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- GMIA (Global Map of Irrigated Areas)
- IWMI LULC map
- GlobCover LC v2
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Leaf area index (LAI) and NDVI
- Net primary production (NPP) and gross primary production (GPP) (MODIS)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- GRACE (Gravity Recovery and Climate Experiment) dataset
- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.

The resolution of the above datasets varies from 250 m (MODIS) to 300 km (GRACE). However, all the dataset will be re-sampled to 250 m x 250 m resolution to develop water accounts of the study sub-basins/basins.

7. Project Budget

Head	**Amount (in Lakh)**		
	1stYear	2nd year	Total
1: Manpower: JRF@31,000/ + HRA and others	-	-	-
2: Work Station-high configuration	3.50	-	3.50
2: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	2.00
3: Travel Expenditure	1.50	1.50	3.00
4: Contingency	0.25	0.25	0.50
Grand Total			**9.00**
	Rs. Nine Lakhs only		

8. Expected Deliverables

- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Land Productivity and Water Productivity.
- Basin/sub-basin wise Water Accounts: Supply-Demand and Consumptions and Water Availability
- WALU map, soil maps and river networks.
- WA+ Report and Recommendations of best practices suitable for the catchments
- Trainings on WA+ to the officers from Meghalaya WRD and other Implementing Agencies of the NHP.

9.Expected Timeline against the Deliverables:

Project Year	Apr. 2021-Mar. 2022				Apr. 2022-Mar. 2023			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
a. Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments								
b. Data analysis in WA+ Framework, and								
c. Water Consumption Patterns and beneficial non-beneficial consumptions								
d. Accounts of Land Productivity and Water Productivity								
e. Catchment wise Water Accounts: Supply-Demand and Consumptions and Water Availability								
f. WA+ Report and Recommendations of best practices suitable for the catchments								
g. Training modules on WA+								

10. Progress till date:

Particulars	Work Done
Procurement of High Configuration System	Completed.
Generation of GIS layers for 3 basins and 9 sub-basins in Nagaland	Completed.
Data downloading and processing from open sources viz. CHIRPS, GMIA, LAI, GPP, NPP, Globcover, MIRCA (Rainfed and Irrigated), WDPA, Population, etc.	Completed.
Development of Water Accounting based Land use (WALU)	Completed.
Setting up of WA+ model for Sheet 2 (Evapotranspiration) and Sheet 3 (Agricultural Services including Land and Water Productivity) Generation	Completed.
Setting up of Water Pix model for Supply Generation	Completed.
Generation of Sheet 4 (Utilized flow), Sheet 5 (Surface water), Sheet 6 (Groundwater), Sheet 1 (Resource base)	Completed.
Training on WA+ to selected WRD officials	Organized during the month of November, 2022.
WA+ Report and Recommendations of best practices suitable for the catchments	Ongoing

TECHNICAL CELL

Scientific Manpower

S N	Name	Designation
1	Er. Omkar Singh	Scientist G & Head
2	Dr. (Mrs.) Jyoti P. Patil	Scientist E (NHP)
3	Sri Rajesh Agrawal	PRA
4	Sri N. R. Allaka	SRA

APPROVED WORK PROGRAM FOR THE YEAR 2022-23

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	NIH	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sep 2020-Feb 2023	On-going
2	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Sep 2020-Aug 2023	On-going
3	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	NIH	A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Sep 2020-Aug 2022	On-going
4	Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun	NIH	Omkar Singh (PI) V.C. Goyal, Rajesh Singh (Co-PI), Jyoti Patil, Rohit Sambare, N.R. Allaka; Team from SRHU-HIHT, Dehradun	April 2022-Mar 2024	Proposed to drop the study due to non availability of requisite data/resource
Sponsored Projects					
1	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI)	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	On-going

RECOMMENDED WORK PROGRAM FOR THE YEAR 2023-24

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	NIH	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sep 2020- Feb 2023 (sought ext. till June 23)	On-going
Sponsored Projects					
1	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI)	Omkar Singh (PI), V.C. Goyal (ex PI), Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Rajesh Agarwal, NR Allaka, Project Staff (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	On-going

Study- 1 (Internal)

1. Title of the Study: Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand Region, Central India.

2. Project team:

d. Project Investigator: Dr. Jyoti P. Patil

e. Project Co-Investigator(s):

Dr. T. Thomas (RC-Bhopal)
Dr Prabhash K Mishra
Er. Rohit Sambhare
Dr. V. C. Goyal (*Retired in Sept.2022*)

3. Type of Study: Internal; **Budget**: 41.0 Lakhs (*Expenditure: Nil*)

4. Date of start: 01.09.2020

5. Scheduled date of completion: 28.02.2023 (*Request to extend upto June 2023*)

6. Duration of the Study: 2.5 years (30 months)

7. Study Objectives:

The major objective of the study is to assess the demand and availability of water in Upper Dhasan basin located in the drought prone Bundelkhand region in Central India, and to develop a plan for the optimal water allocation using WEAP model and WA+ framework.

8. Statement of the Problem:

The Dhasan River is a major tributary of the Betwa river system which originates in Raisen district of Madhya Pradesh and flows through the various drought prone districts in Central India viz., Sagar, Tikamgarh, Chhatarpur districts in MP and Lalitpur, Jhansi and Hamirpur districts in UP. It is one of the important rivers in Bundelkhand region which has off late become a drought prone region due to the various issues facing the region including the overexploitation of the natural resources and changes in the weather pattern. The frequency of occurrence of droughts is once in 4 years. The variability of rainfall is the main reason for the regular water stress. However, the limited groundwater availability in the hard rock region coupled with low water holding capacity soils further aggravate the water stress thereby creating livelihood issues for the local population.

This study aims to have a holistic look into the overall water availability in the Dhasan basin, in the light of the committed storages of the planned projects and realistic assessment of the planned projects. The estimation of the water availability and water productivity using both the WEAP model and the Water Accounting+ framework in totality will help to understand the supply of available water along with the demands from various sectors in the drought prone region in Bundelkhand. The assessment of the reliability of these projects in the light of the climate change, based on scenario analysis for the estimation of the future water supply-demand and development of an optimal water allocation plan for the basin, shall provide a useful tool in the hands of the decision makers to fine-tune the water resources development and management policies accordingly. The State Government is interested in taking up such a project as this will provide them with an optimal water allocation plan in the present time as well as into the future. The Chief Engineer, BODHI, MP Water Resources Department has given the consent in this regard.

The water availability needs to be assessed for multiple scenarios of new and upcoming water storage infrastructure, plans for out of the basin water transfers as well as the highly uncertain impacts of the climate change on the water availability scenario in the basin. This will provide as realistic assessment of the present and future water availability scenario in the basin based on optimal water allocation policies and plans can be devised. Such an integrated effort will go a long way in managing the available water resources in the present and future and managing the demands in tune with the availability and constraints. This will result in the development of WEAP and WA+ based water allocation plan for the optimal use of water resources in the study area, which will be useful to the line departments and stakeholders including the Agriculture Department (agriculture), Water Resources

Department (better water distribution for irrigation by integrated operation of projects), Public Health Engineering Department (water supply for domestic use) and Industries that may be benefitted, ultimately leading to the development of the region resulting in improved livelihood options for the local population.

9. Methodology

Study area:

The study has been selected in Upper Dhasan basin upto Garrauli G/D site on Dhasan river falling in Chhatarpur district (Figure 1). The area of Upper Dhasan Basin is 3565 sq. km.

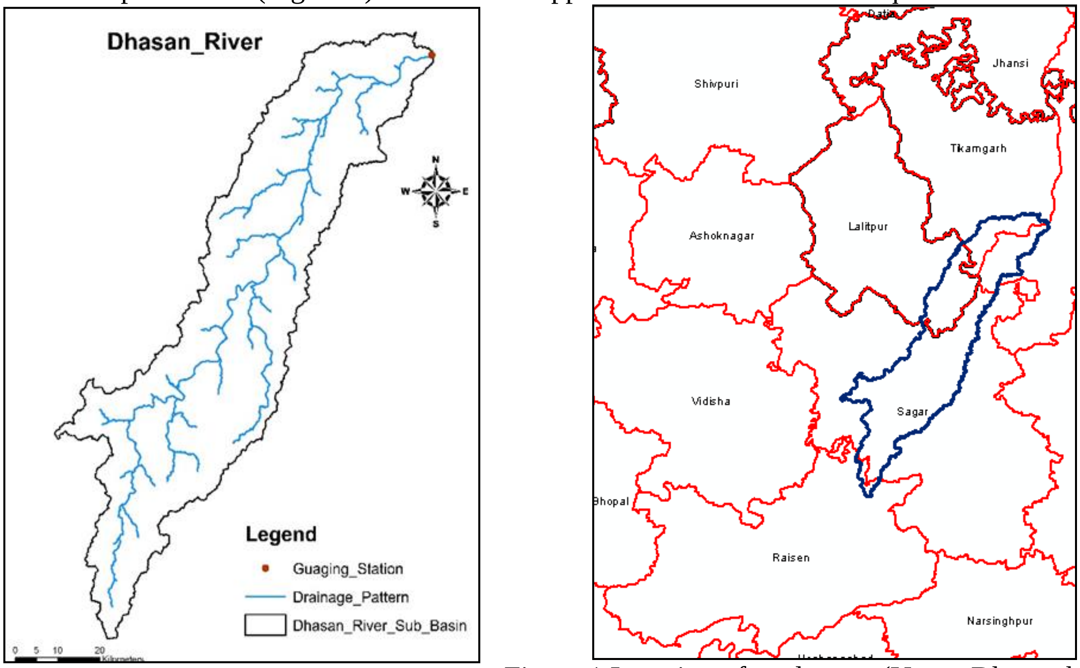


Figure 1 Location of study area (Upper Dhasan basin)

Detailed Methodology:

1. Preparation of data inventory including climatic, hydrologic, demographic and socio-economic data.
2. Processing and analysis of data.
3. Trend analysis of meteorological and hydrological variables.
4. Customization, calibration and validation of WEAP model for runoff simulation.
5. Estimation of water productivity and land productivity using WA+ framework
6. Assessment of environmental flow requirement using established techniques and water balance and supply demand scenario using WEAP and WA+ outputs.
7. Vulnerability assessment using IPCC approach
8. Assessment of climate change on the future water availability.
9. Water allocation planning for the present and future under alternate scenarios of upcoming water resource infrastructure, population growth, inter-basin water transfer and climate change using WEAP.
10. Stakeholder workshop and Final Report.

10. Analysis & Results

1. **Collection of information and Hydro-meteorological Data**

   a. The gauge and discharge data of Garaulli site, Madhya Pradesh was collected from Yamuna Basin Organization (YBO), Central Water Commission (CWC), Government of India from 1991-92 to 2019-20.

   b. The daily meteorological data [Rainfall, Temperature (maximum and minimum)] of 17 grid points have been collected from IMD, Pune for 50 years (1971-2020).

The details of hydro-meteorological, spatial, and agriculture data is given in the following table1.

Table 1 Details of hydro-meteorological data

Data	Details	Source
Discharge data (Daily)	1991-92 to 2019-20	CWC
Rainfall (Daily)	0.25° X 0.25° ; 1971-2020	IMD
Temperature (Daily)	1° X 1°; 1971-2019	IMD
Geospatial Maps	Land use Land Cover (LULC) River and Water bodies Soil type	USGS earth explorer, NRSC
Agriculture	Major crops (kharif/ rabi), area under each crop, water requirements, irrigated area	Respective District Administrations, District Irrigation Plans (DIP)
Demand data	Population Livestock Industries	Census/ District Administration websites / District reports
Supply information	Water Supply, Groundwater source Tank capacity	IMD/ district authorities CGWB district reports Minor irrigation census

2. Spatial database

The spatial database of the basin such as Digital Elevation Map (DEM), LULC map, Drainage Network were created. The landuse of the basin is predominantly agriculture (58%). The area under each landuse is given in Table 2.

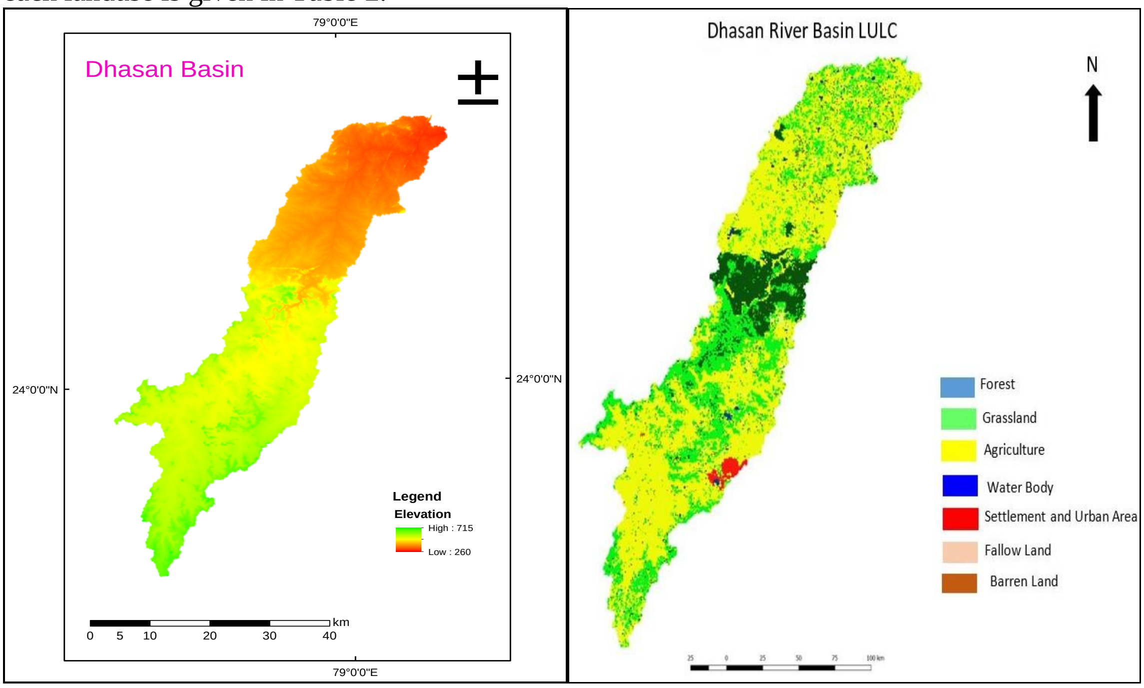


Figure 2 DEM and LULC maps

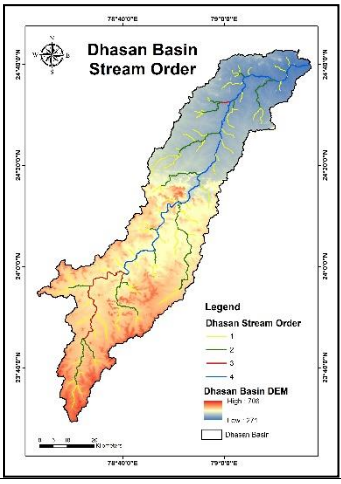
Table 2 Land use/land cover statistics of Dhasan river basi**n**

Land use/cover categories	Area (km^2)	Percentage (%)
Agriculture Area	1982.23	58
Grassland	959.58	28
Forest Area	304.91	9

Barren land	74.02	2
Fallow land	58.20	2
Urban area	29.41	1
Water bodies	18.04	1

3. Morphometric Analysis of Upper Dhasan Basin

Morphometric Parameter	**Value for basin**
Area (A)	3565 km^2
Perimeter (P)	714 km
Maximum Elevation (H)	706 m
Minimum Elevation (h)	271 m
Length (L_b)	136.62 km
Highest Stream Order (U)	4
Stream Number	231
Stream Length	751 km



Derived Parameters				
Morphometric Parameter	**Value for basin**		**Morphometric Parameter**	**Value for basin**
Mean Stream Length (L_{sm})	3.9 km		RHO coefficient	0.162
Bifurcation Ratio (R_b)	7.095		Relief (B_h)	435 m
Stream Length Ratio (R_1)	3.44		Relief Ratio (R_h)	3.184
Mean Bifurcation Ratio (R_{bm})	2.37		Relative Relief (R_{hp})	98.880
Mean Stream Length Ratio (R_{1m})	1.15		Ruggedness Number (R_n)	91.785
Stream Frequency (F_s)	0.065 km^{-2}		Circulatory Ratio (R_c)	0.088
Drainage Density (D_d)	0.211 km/km^2		Elongation Ratio (R_e)	0.493
Drainage Texture (D_t)	0.323 km^{-1}		Form Factor (F_f)	26.094
Length of Overland Flow (L_o)	2.37 km		Lemniscates Ratio (K)	1.310
Drainage Intensity (D_i)	0.308 km^{-1}		Compactness Coefficient (C_c)	3.373

4. Analysis of meteorological and hydrological variables

For modeling purpose, the basin is divided into two catchments. The sub-watershed 1 (SW1) is upto Banda Irrigation project and sub-watershed 2 (SW2) is downstream of the Banda irrigation project, upto the outlet of the basin. The Table-3 summarizes indices estimated for SW1 and SW2 alongwith their trend using Kendall-tau significance test.

Table 3 Indices estimated for SW1 and SW2

Index	SW1		SW2	
	Value	Trend statistics	Value	Trend statistics
Mean Tmax (^{0}C)	32.56	0.0226	32.52	0.0172
Mean Tmin (^{0}C)	18.43	0.0193	18.96	0.0161
Mean Rainfall (mm/day)	2.91	-0.0044	2.78	-0.0082
No. of days RF>= 10mm	28.96	-0.0742	29.80	-0.1205
Max no. consecutive dry days (during Jun, Jul, Aug)	15	-0.1838	15	-0.1021
Max no. consecutive wet days (during Jun, Jul, Aug)	8	-0.0323	10	-0.0249
Greatest 3-day total rainfall (mm)	183.72	0.3426	170.82	-0.1295
Greatest 5-day total rainfall (mm)	219.28	-0.2357	210.08	-0.3429
Greatest 10-day total rainfall (mm)	301.61	-0.5746	282.53	-0.677

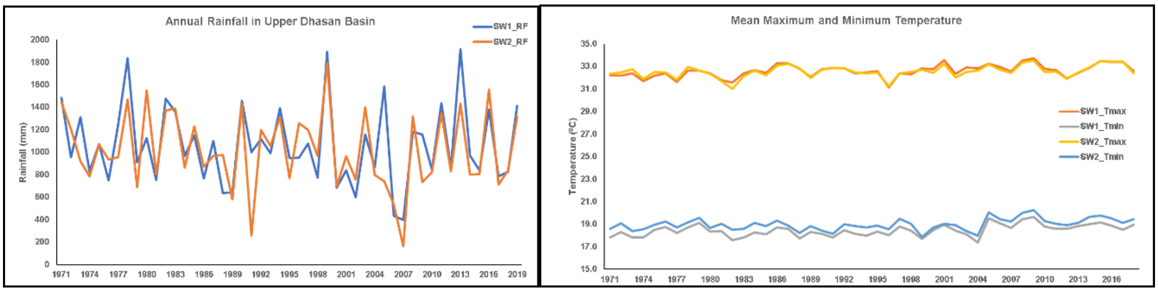


Figure 3 Annual rainfall and mean temperature variation in basin

5. Drought analysis: Meteorological drought analysis is completed using the observed data of the basin

6. WEAP model formulation

The WEAP model for formulated for complete Upper Dhasan Basin for the current account year 2015 by considering demands (agriculture, forest, domestic, industrial), supply resources (rainfall, groundwater, river and major surface reservoirs). The scenarios like population growth, increased irrigation efficiency, industrial growth and incorporation of rainwater harvesting structures were run in the WEAP to observe the unmet demands of the basin during 2021-2050.

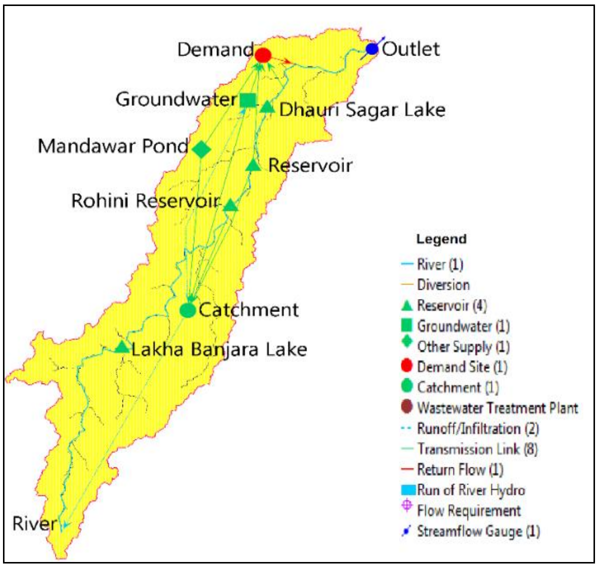


Figure 5 WEAP model formulation for Dhasan Basin

For detail analysis of water balance components and impact of proposed dams in the basin, the WEAP model will be formulated for two sub-catchments.

7. WA+ Framework

Precipitation and Evapotranspiration Variability

A preliminary analysis was carried out to understand the precipitation and evapotranspiration variability across the Betwa basin. Figures 6a shows the spatial variation of precipitation obtained from CHIRPS data (developed by the Climate Hazards Group InfraRed Precipitation with Stations) for the period of 2003-2014. It can be observed that the eastern and southern parts of the Betwa basin receives higher rainfall as compared to the rest part of the basin. Overall, the basin receives less rainfall with an annual average of 958 mm. In the contrary, the mean monthly ensemble ET is higher in the northern and central parts of the basin as shown in Figure 6b.

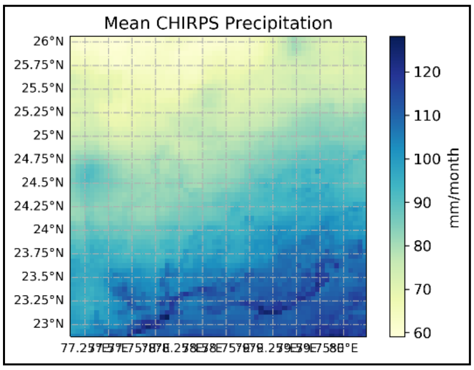


Figure 6a Spatial variation of mean monthly CHIRPS precipitation

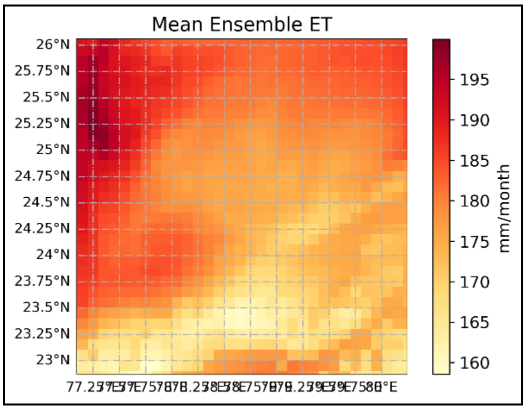


Figure 6b: Spatial variation of mean monthly ensemble ET

WA+ based land use land cover (WALU)

WA+ recognizes the influence of land use on water cycle and provides the link between water balance, land use and water use as well as management options to modify it, by grouping land use classes with common management characteristics. WA+ classifies LULC in to four major LULC classes segregated from 80 global land use classes based on the land use and water management practices as: (1) Protected Land Use (PLU); (2) Utilized Land Use (ULU); (3) Modified Land Use (MLU); and (4) Managed Water Use (MWU). PLU represents areas set aside for minimal disturbance by humans e.g. National Parks & Wildlife Sanctuaries, etc. ULU represents a land use that provides a range of ecosystem services and which has had little interference by man with less exploitation e.g., Grasslands, forest land, natural pastures, etc. MLU refers to land that is significantly modified by human activity. Here only the land use is modified e.g., Rainfed cropping systems, creation of plantation forests, etc. MWU represents the land use classes in which both the land use and water is managed with significant exploitation, e.g. Irrigated cropping systems. The WA+ based land use for the Betwa basin is shown in Figure 7. The land use distribution is presented in Table 4.

Table 4: Land use distribution for the Betwa basin generated using 8 different datasets

LULC	**Area (Km^2)**	**% area**
Forest	3828.25	10.62
Grassland	3756.81	10.42
Waterbody	1330.06	3.69
Barren/waste	2892.94	8.02
Builtup	6223.25	17.26
Agriculture	18018.44	49.98

Note: Distribution has been generated using 8 global datasets.

Development of Evapotranspiration Sheet [Sheet 2]

Sheet 2 presents provides information on water consumption in a basin as a total value and per water sector (land use type). Major inputs for the generation of Sheet 2 are RS-based evapotranspiration maps (ET), Leaf Area Index (LAI), Net primary production (NPP), Gross primary production (GPP), daily precipitation and a LULC map. Developed Sheets for wet and dry year for the Betwa basin is shown in Figure 8a and Figure 8b, respectively. The total water consumptions of the basin for the wet year, i.e., 2013-14 is found to be 41.5 km^3/year with further partitioning of ET into evaporation (E) from soil and Transpiration from different LULC. The total water consumptions of the basin for the wet year, i.e., 2013-14 is found to be 25.8 km^3/year. Sheet 2 also shows that the non-beneficial consumptions in the basin indicating further scope for water conservation practices to be adopted in the basin to minimize non-beneficial consumptions.

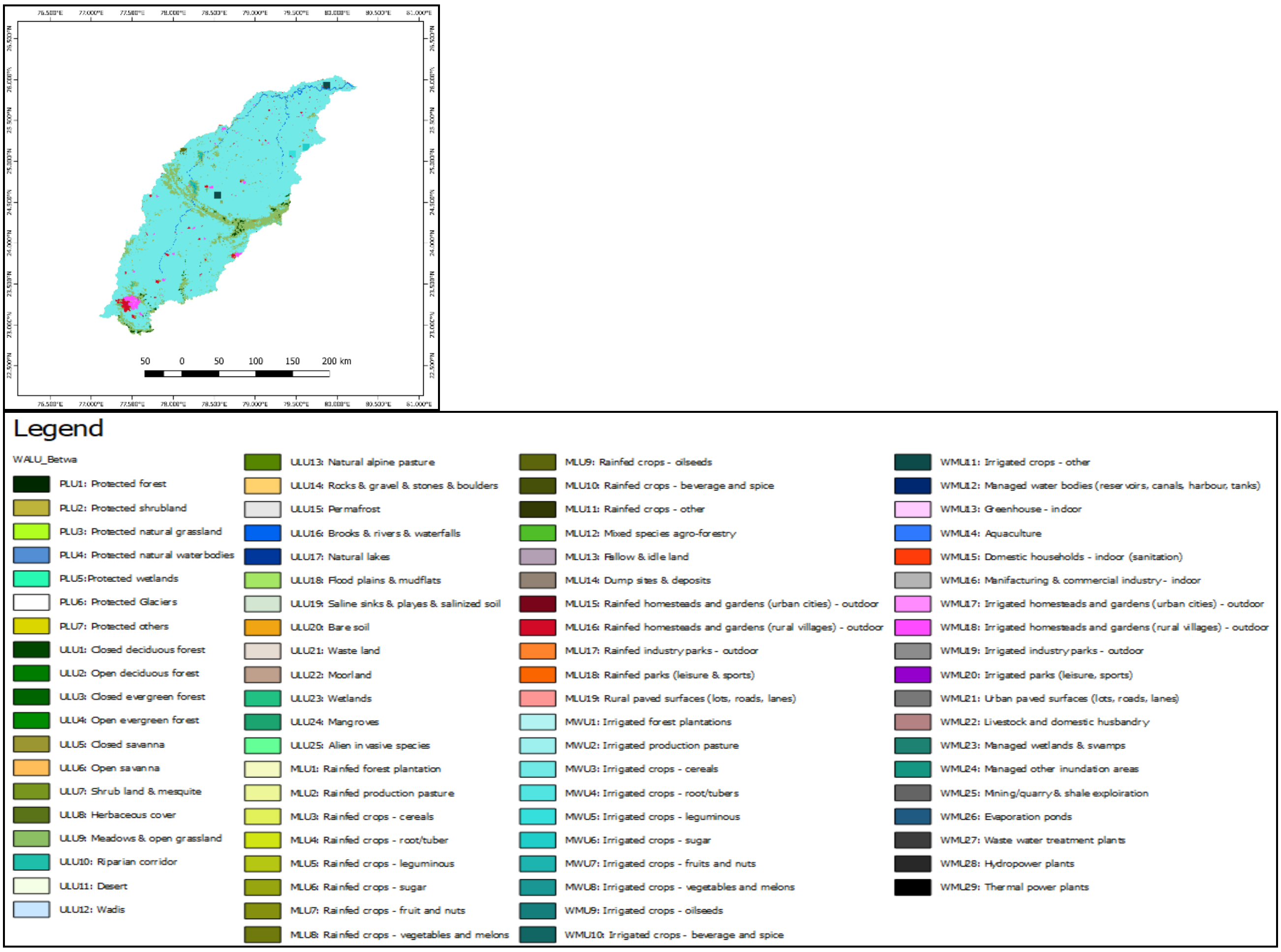


Figure 7: LULC map of Betwa basin generated using WALU

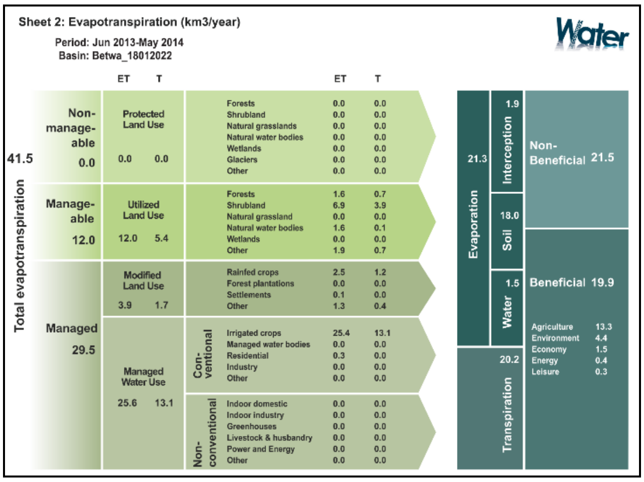


Figure 8a: Evapotranspiration Sheet: Sheet 2 for wet Year 2013-14.

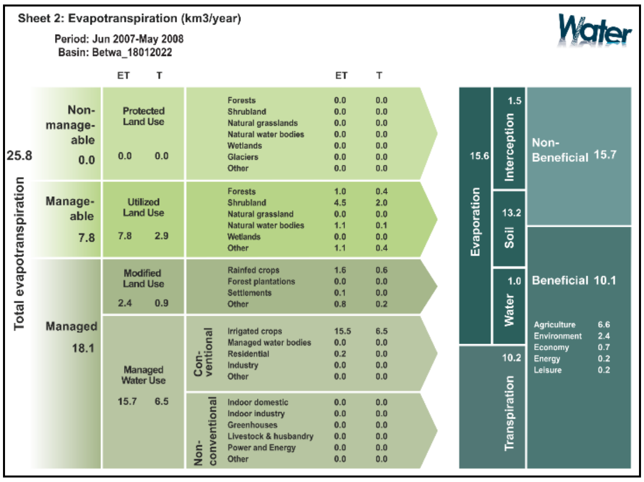


Figure 8b: Evapotranspiration Sheet: Sheet 2 for Dry Year 2007-08.

11. End Users / Beneficiaries of the study: Agriculture Department (agriculture), Water Resources Department (better water distribution for irrigation by integrated operation of projects), Public Health Engineering Department (water supply for domestic use) and Industries.

12. Major items of equipment procured: None.

13. Lab facilities used during the study: None.

14. Data procured or generated during the study: Spatial database of the study area

15. Output of the study:

- Nivesh, S, **Patil, Jyoti P.**, Goyal, V.C., et al. (2022) Assessment of future water demand and supply using WEAP model in Dhasan River Basin, Madhya Pradesh, India. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-022-24050-0 (**IF:5.19**)
- Sambhare R. and **Patil, Jyoti P.** (2023) Quantitative Morphometry Analysis of Upper Dhasan River Basin, Bundelkhand region, Central India. Special Edition on Mission LiEF (Lifestyle for Environment). IIT(ISM) Dhanbad (*Submitted*).

16. Study Benefits / Impacts: Outputs of the study will be used in preparation of 'Integrated Water Management Plans at Sub-basin level and District level.

17. Shortcoming / Difficulties: The stakeholders workshop with the beneficiaries is to be conducted for sharing the findings of the study and taking feedback of the line departments

18. Future Plan: The stakeholders workshop is proposed to conduct during May 2023 and Final report of the study will be submitted by June 2023.

Ongoing Sponsored Project-DST

1. Title of the project: Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)

2. **Study Team:** Er. Omkar Singh (PI), Dr. V.C. Goyal (Former PI), Dr. Rajesh Singh (Co-PI), Dr. Jyoti P. Patil, Er. Rohit Sambare, Rajesh Agarwal, NR Allaka
NIH Project Team: Dr. Jyoti Singh, Dr. Shweta Yadav, Ms. Ritika Negi
Project Partners: NIH-Roorkee, MNIT-Jaipur, IIT-Bombay, IRMA-Anand

3. Funding: DST (GoI), Cost: Rs. 5.1 Crore

4. Duration: Apr 2019-Mar 2024

5. Objectives of the study

The project **'Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)'** is funded by Department of Science & Technology (DST), Government of India. The National Institute of Hydrology (NIH) Roorkee is the leading institute for implementation of this project, in collaboration with the project partners from Indian Institute of Technology Bombay (IITB), Malaviya National Institute of Technology (MNIT), Jaipur and Institute of Rural Management, Anand (IRMA). The objectives of the project are:

- **Objective 1**: Establishment of a state-of-art Centre for Eco-prudent Wastewater Solutions (IC-EcoWS) to harness the potential Natural Treatment Systems (NTS) and other eco-prudent resource recovery technologies for water security and sustainability in India,
- **Objective 2**: Development of a Decision Support Tool (DST) based on Life Cycle Assessment (LCA) and Multiple Criteria Decision Making (MCDM) approach for selection of appropriate "Technology Packages" for resource recovery oriented wastewater treatment infrastructure,
- **Objective 3**: Establishment of few pilot study sites ("Live Laboratories") for detailed assessment of selected NTS in urban, peri-urban and rural settings, for both secondary and tertiary treatment requirements as per new CPCB norms as well as for select emerging pollutants,
- **Objective 4**: To explore innovative ideas on the development (e.g. use of pre-fabricated structures, efficient structures for control of solid waste in sullage) and application (e.g. retrofitting of existing village ponds, drains, linkage to livelihood options) of NTS for wastewater treatment,
- **Objective 5**: To organize capacity building, awareness creation, documentation and dissemination activities, and preparation of a TOT Module on NTS applications and an Indian handbook for promotion and propagation of NTS for resource recovery and wastewater treatment in India.

6. **Results achieved with progress/present status:** The Progress of project at NIH is given below:

Milestones	Activities	Target Month	NIH-Progress
Hiring of Project staff	Hiring of project staff	M6	Completed
Dev. of Centre Portal	Development of IC-EcoWS Centre Website and social media pages for information dissemination	M12	Completed
Organization of Users interactions Workshop	IC-EcoWS Project Inception Cum Need Assessment Workshop (8-9 August, 2019)	M12	Completed
	Report on First Annual Workshop- IC-EcoWS Project Inception Cum Need Assessment Workshop		
Establishment of Live Laboratories	Procurement of several technical and scientific lab equipment for setting up the IC-EcoWS Innovative Centre at NIH Roorkee	M18	Completed
	Establishment of horizontal sub-surface -flow constructed wetland for domestic wastewater treatment (Peri-urban residential area in Roorkee)		
	Installation of Online Monitoring System for water quality monitoring		
Development and Application of Innovative ideas on NTS	Pilot-scale natural treatment system (4 cell floating wetlands) for the treatment of domestic wastewater using identified plant species *Bacopa monnieri* and *Acorus calamus*	M24	Completed
	Treatment of domestic wastewater using floating treatment wetlands using *Phragmites australis*, and *Canna indica*	M30	Completed
	In-situ treatment of domestic wastewater in urban drain using floating constructed wetland/Bio-Inoculum-Solanipuram/Adarshnagar (Roorkee)	M36	Completed
	Pilot-scale demonstration unit for wastewater treatment of residential building using SSHF Constructed wetlands system at NIH Roorkee	M36	Completed
	Pilot-scale horizontal sub-surface-flow constructed wetland (HSSFCW) for Pesticide (chlorpyrifos) removal from synthetic wastewater using *Canna indica* in NIH Roorkee.	M49	Ongoing
	Lab-scale study to estimate biogas generation from *Canna indica* biomass collected from Subsurface Horizontal Flow Constructed wetlands system at NIH Roorkee	M52	Ongoing
	Performance evaluation of horizontal sub-surface-flow constructed wetland (HSSFCW) for the treatment of domestic wastewater at NIH Colony (Real-time Monitoring of Water quality parameters)	M55	Ongoing
Documentation and dissemination	Capacity building, awareness creation, and dissemination activities (Factsheets/policy briefs, reports on NTS)	M58	Ongoing

HARD ROCK REGIONAL CENTRE BELAGAVI

Scientific Manpower

S N	Name	Designation
1	Dr.B.Venkatesh	Scientist G & Head
2	Dr. M K Jose	Scientist F
3	Dr.Chandra Mohan T.	Scientist D
4	Mr. Abhilash R.	Scientist C
5	Dr.N. Varadarajan	Scientist B
6	Sh.Chandrakumar S	PRA
7	Sh. Amit Sharma	RA

The progress of each study for the year 2022-23 was presented by the respective PIs of the study. The comments/actions suggested by the RCC for various studies are presented in Table-1:

Table 1: Comments and suggestions by the RCC members on work program of 2022-23

SN	Project	Study Team	Duration	Status & Comments/ suggestions
INTERNAL STUDIES				
1.	Monitoring and Evaluation of Ground Water Quality of Belagavi City, Karnataka, India	Varadarajan N (PI), Chandra Kumar S, Abhilash R	2 year (6/22 to 5/24)	Potential area of expected pollution due to intensified urbanization may be presented on Map for better understanding of the issue. Also, the nearby water bodies and semi-urban area surrounding the Belagavi city may be presented on the map.
SPONSORED PROJECTS				
1.	Groundwater Model Development In Micro Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana	B Venkatesh(PI), M K Jose, Sudhir Kumar, Abhilash R & Officials from TSGWD	*3 years* (Sep 2019 – Aug 2022 Extended upto August 2023	Chairman suggested that as steady state modelling is completed, the transient state modelling be taken up to develop different scenario should be completed to achieve the objectives. Committee suggested to consider the recharge values under each of the land use and from Canal and river independently to represent the impact of changes in the area. The PI informed that members, the final report will be submitted before the July 2023
2	Impact Of Sand Mining On Groundwater Regime In Parts of Manjira River Basin, Telangana State	M K Jose (PI), B Venkatesh, Chandramohan T, Abhilash R and Officials form TSGWD	*2 years* Sep 2021 – Aug 2023	Status report is ready to be submitted.
3	Comprehensive Assessment of Water Availability, Use and Issues for Goa State	B Venkatesh (PI), Chandramohan T, Abhilash R and Officials of WRD Goa	2 years (01/22 to 12/23)	Prof. Lakshman suggested to consider the impact of land-use changes in the future. Also, Dr. Sen Gupta suggested to consider the different climate scenario under the AR-6 so as to assess the future water availability.

TO CONSIDER FOR THE PROPOSED WORK PROGRAM FOR THE YEAR 2023-2024.

The studies which will continue from the previous year and the new studies proposed for 2023-24 were presented. After discussion and deliberations, the RCC recommended the studies for the work programme of 2023-24 as given in Table 2.

Table 2: Proposed work program for the year 2023-24

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Monitoring and Evaluation of Ground Water Quality of Belagavi City, Karnataka, India	Varadarajan N (PI), Chandra Kumar S, AbhilashR	2 year (6/22 to 5/24)	On-Going
	Comprehensive Assessment of Hydrology of Large Rivers basins of Western Ghats of Karnataka	Venkatesh.B (PI), Abhilash.R, N. Varadarajan	3 year (4/23-4/26)	The chairman suggested include the impact of land use on the discharge. Prof. Lakshman suggested to include the Environmental Flow Requirement (EFR) as one of the component. Also, Dr. Sen Gupta, suggested to include the climate change issue so as to assess the future water availability.
	Studies on Occurrence, Distribution of Springs in parts of Western Ghats, India	Abhilash.R (PI),Venkatesh.B,	1 year (4/23-3/24)	Committee suggested to develop a comprehensive information system of the springs so it is available for scientific community
	Water Productivity assessment in Irrigation Projects by Geo-Spatial Optimization Techniques	Abhilash.R (PI),Venkatesh.B,	3 year (4/23-4/26)	Committee advised to select an area in which sufficient data is available
SPONSORED PROJECTS:				
1.	Groundwater Model Development In Micro Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana	BVenkatesh (PI), MKJose, Sudhir Kumar, Abhilash R & Officials form TSGWD	*3 years* (Sept 2019 – Aug 2022 Extended upto August 2023	Special Studies under NHP
2.	Impact Of Sand Mining On Groundwater Regime In Parts of Manjira River Basin, Telangana State	MK Jose(PI), B Venkatesh, Chandramohan T, Abhilash R and Officials form TSGWD	*2 years* Sept 2021 – Aug 2023	Special Studies under NHP

S. N.	Project Title	Study Team	Duration	Status
+3	Comprehensive Assessment of Water Availability, Use and Issues for Goa State	BVenkatesh, ChandramohanT, AbhilashR and Officials of WRD Goa	2 years (01/22 to 12/23)	Special Studies under NHP

WESTERN HIMALAYAN REGIONAL CENTRE JAMMU

Scientific Manpower

S N	Name	Designation
1	Dr P G Jose	Scientist E & Head
2	Dr. Riyaz Ahmed Mir	Scientist C
3	Sh. Sachchidanand Singh	Scientist B
4	Sh. Ishan Sharma	Scientist B
4	Sh. Gurpreet Singh	RA

WORK PROGRAM FOR THE YEAR 2022-23

Progress of Ongoing Studies

S. No.	Title of Study	Team	Duration	Remarks
Internal Studies				
1.	Estimation of changes in snow cover and climate-cryosphere interaction in Upper Chenab river basin	P. G. Jose D. S. Bisht	02 Years 07 months (Aug. 2020 – Mar. 2023)	Ongoing (Extn. up to Oct. 2023 requested)
2.	Early signatures of 21st Century on snow cover dynamics in Zanskar river basin, Ladakh	D. S. Bisht P. G. Jose	02 Years (July 2021 - June 2023)	Ongoing (Extn. up to Dec. 2023 requested)
3.	Investigation of hydrodynamic approach of flood inundation mapping and assessment of changes in river planforms using a cloud-based GEE platform in data-scarce Western Himalayan basin	R. V. Kale A. K. Lohani J. P. Patra D. Khurana	03 Years (Sept. 2021-July 2024)	Ongoing
4.	Mass balance of Phuche and Khardung glaciers, Ladakh with implications for downstream water availability under changing climate.	P. G. Jose D. S. Bisht D. Khurana	03 Years (July 2021-June 2024)	Ongoing
5.	Comparative analysis of fine-scale satellite & reanalysis precipitation products in UGB using Multi-Criterion Decision-Making	D. S. Bisht M. K. Goel	01 Year (June 2022 – May 2023)	Ongoing (Extn. up to Dec. 2023 requested)
Externally funded R & D Studies				
1.	Web-enabled inventory of natural water springs of Tawi river catchment of J&K State of India for vulnerability analysis and developing adaptive measures for sustaining Tawi river	S. S. Rawat P. G. Jose S. Gurjar D. S. Bisht	03 years (April March 2019 to 2022)	Completed study funded by NMHS (2 Co-PIs at WHRC)
2.	Permafrost mapping and characterization of Western Himalayan Region	P. G. Jose A. P. Dimri (JNU) G. Jeelani (KU) V. Agnihotri (GBPNIHESD)	04 years (Aug 2019 – Aug 2022 and extended up to Mar 2024)	Ongoing study funded under NMHS, GoI.

1 Estimation of changes in snow cover and climate-cryosphere interaction in Upper Chenab River basin

PGJ made a presentation of the progress achieved in the project. For estimating the extent and variability of snow cover in the Upper Chenab Basin, global MODIS snow products from TERRA satellite, viz, MOD10A2 - an eight-day composite land surface reflectance product was employed. The entire basin was divided into different zones on the basis of elevation (3 zones), slope (6 zones), and aspect (8 zones). In order to extract these features, ALOS Global Digital Surface Model available at 30 m spatial resolution was used. Only snow cover imageries with less than 15% cloud cover were selected. The results reveal that while, almost the entire basin was snow covered between February and April during 2000-2020, minimum snow cover was observed in the month of August. The inter-annual variability in monthly snow cover depletion over the study period was studied in relation to precipitation and air temperature variability. Highest & lowest slopes gave lowest snow cover depletion, of which lowest slopes could be glacier tongues or avalanche toes. A slight reduction in average annual precipitation and a significant increase in average annual air temperature (0.3 ºC) coupled with a shift in peak winter precipitation from March to February and monsoon peak from July to August was observed during the first two decades of 21st century as compared to the last five decades of 20th century.

Estimation of specific mass balance of select glaciers (Chhota Shigri and Bara Shigri) in the basin was attempted using modified Area Accumulation Ratio (AAR) method. AARs estimated for Chhota Shigri Glacier using Landsat data with NDSI values of 0.4 gave comparable values under automatic as well as supervised classification, in most hydrological years between 2002 and 2019 for which field glaciological data were available. Development of regression equation between in-situ and modified AAR mass balances is ongoing. Temperature data analysis at daily resolution is yet to be taken up.

MKG queried whether snowmelt data can be measured so that relationships be established with modelled values. Dr. S. R. Shah (SRS) asked whether differentiation of snowmelt and glacier melt can be assessed through this work. PGJ replied that although differentiation of snowmelt and glacier melt was not an objective, discharge data of CWC at Tandi can help to verify the estimation of melt derived discharge for the study area. The PI requested for extension of the project up to October 2023. The Chairman directed the PI to complete the project by October 2023.

2 Early signatures of 21st Century on snow cover dynamics in Zanskar river basin, Ladakh

Dr. Deepak Singh Bisht (DSB) presented the work progress of the project and discussed the salient findings. For examining the variation in maximum snow cover extent and its variability in Zanskar River basin for the first 20 years of 21st century, MODIS snow products from TERRA satellite, viz, MOD10A2 - an eight-day composite land surface reflectance product is downloaded. A total of 939 MOD10A2 images were downloaded for period 2000-2020 and are being analysed to study the snow cover dynamics of the basin. For investigating the influence of global warming induced due to climate change on the snow cover dynamics, ERA5-Land hourly data of total precipitation and air temperature available at 9 km spatial resolution is procured. Prior to analyzing the hourly data, monthly reanalysis data from ERA5 at monthly temporal scale was analyzed. DSB informed that good amount of precipitation occurs during months from Dec. to Feb. due to western disturbance in the region, whereas lesser precipitation occurs during the monsoon months. Mean monthly rainfall of the basin is found to be 45 mm while the mean temperature is found to be -9.9 ºC, and only few months show positive temperature during monsoon season.

While analyzing the first 20 years of data of 21st century, it was found that mean temperature of the basin has increased by 0.4 ºC. Daily temperature records were extracted from the hourly ERA5 reanalysis product to analyse the trend in grid-wise maximum, minimum and average temperature in different climatic windows of 30 year period since 1950. Besides analysing the trend in 30 year climatic windows, i.e., 1951-1980, 1961-1990, 1971-2000, 1981-2010, and 1991-2020, long term trend for the period 1950-2020 were also analysed. Overall, a warming trend was observed in the region with inter-annual variability in the temperature regime. For trend analysis, non-parametric test, i.e., modified Mann-Kendall trend detection test was employed.

Chairman asked whether data of ERA5 has been compared with any ground data to which the DSB replied that there is no ground station data available for this region. PGJ added that IMD has started monitoring the region very recently and have set up station for data observance. Chairman also asked the PI to observe that the trend between ISM and WD rainfall patterns is similar and therefore needs to be re-analysed further to draw inference and establish linkages. Chairman approved the extension of the project by 6 months.

3 Investigation of hydrodynamic approach of flood inundation mapping and assessment of changes in river planforms using a cloud-based GEE platform in data-scarce Western Himalayan basin

Dr. R. V. Kale (RVK) made the presentation on progress of this study. He informed that in the previous study for the Tawi basin, the 1D steady-state HEC-RAS and HEC-HMS models were set up. However, the flood inundation and hazard mapping using two-dimensional model is most appropriate for planning flood management measures in near-real-time. A through literature review has been carried out to formulate the research approach in present study. It was mentioned that the changes in river planform and geomorphic dynamics cause ecological, hydrological and environmental impacts. These river changes can be attributed to processes occurring over multiple timescales. Accordingly, the changes in the Tawi planform during 1988 to 2022, based on the composite Landsat data, have been extracted using GEE code. It has been observed that significant changes in the planform of the Tawi river have occurred during 1988 to 2022 in the lower reaches downstream of the Sidhara gauging station.

Dr. Sanjiv Sandal (SS) suggested to make the presentations less scientific and more understandable to general public with less focus on methodology and more focus on results and recommendations. Er. Manoj Gupta (MG) suggested that such data be shared with the line department as there is already a requirement for flood zone mapping of Tawi catchment. RVK replied that in this study, the focus is to investigate and find out the reasons of the shifting in the river planform, which in turn can be an input for river training works. MKG observed that as accretion is more than erosion, therefore past floods shall be modelled and emulated in current cross-section of the river and flood zone map should be prepared. Chairman asked the PI to focus on the recommendations for policy makers while making the report of the project.

4 Mass balance of Phuche and Khardung glaciers, Ladakh with implications for downstream water availability under changing climate

PGJ made a presentation of the progress achieved in the project. The mass balance series of Phuche and Khardung glaciers is the longest glaciological mass balance data set in Ladakh and will gain further value addition in terms of climate-glacier-water resource linkages and future water resource availability for Leh and surrounding hamlets. As part of the project, field work was carried out in June and October 2022. While annual mass balance data for 2022 could not be collected because of a tragic road accident involving field assistants associated with the project, data from four Automatic weather stations (AWS) and an Automatic Water Level Recorder (AWLR) from the glacier catchment were retrieved and analysis of these data sets is going on. The results show much more negative mass balance in case of Khardung glacier as compared to Phuche glacier, possibly due to the proximity to the National Highway. The analysis of stream gauge record revealed significantly higher discharge in the evenings in the first half of the melt season while post the seasonal melt peak, there is little difference between morning and evening discharges. A spring event in the middle of June, with a sudden increase in stream gauge was also observed. A broadly inverse relationship between stream gauge and electrical conductivity was observed during most of the melt season, indicating dilution effect, whereas the spring event that occurred mid-June saw a sharp increase in both discharge and solute load, indicating that a long residence time in contact with glacier-eroded chemically active rock debris.

Chairman suggested that Discharge Vs EC inverse relationship should be analysed further. Chairman also emphasised on the need to continue this work.

5 Comparative analysis of fine-scale satellite & reanalysis precipitation products in UGB using Multi-Criterion Decision-Making

DSB made a presentation on the progress of the study. Primarily, the fine resolution precipitation product available from the satellite estimates, i.e., GPM and reanalysis products i.e., ERA5 and IMDAA were downloaded to compare them with the station records. In this regard, the gridded precipitation estimates were analysed for their suitability in capturing the regional precipitation cycle. The preliminary evaluation were made employing the statistical performance indicators, i.e., Root-Mean-Squared-Error, Correlation Coefficient, Nash-Sutcliffe Efficiency, and Percent Bias. DSB further elaborated the MCDM and GDM approach that are to be employed for identification of best suited products for the region. The Chairman approved the extension for the project for 6 months.

6 Web-enabled inventory of natural water springs of Tawi river catchment of J&K State of India for vulnerability analysis and developing adaptive measures for sustaining Tawi river

DSB made the presentation on the completed study under NMHS. A total of 471 springs were geo-tagged and analysed for their physical and chemical characteristics and data is made available through a WebGIS portal, i.e., Information System for Himalayan Spring for Vulnerability Assessment and Rejuvenation (ISHVAR). He apprised the members that the web portal is developed using the open source tools and the data was collected through electronic means. Results pertaining to spring water quality, discharge, and springshed identification for selected springs were also presented along with various outreach activities and training programs that were carried out in the project.

The Chairman suggested that while preparing presentations, location should always be put on maps for better visualization and understanding. Chairman asked the Co-PI to plot Elevations Vs TDS graph and analyse the results and investigate further.

7 Permafrost mapping and characterization of Western Himalayan Region

PGJ made a presentation of the progress achieved in this multi-disciplinary, multi-institutional project. The project aims to model the permafrost extent and active layer thickness in Leh District, Ladakh and quantify the fluxes of various climatic factors in the permafrost region to find the contribution of ground ice melt in the regional water resources. Additionally, it seeks to understand the water quality and biogeochemistry of the permafrost horizon. As part of the project, thirty-five ground temperature sensors were installed in 2020 and data from most of these sensors were retrieved in September 2021. Soil and water samples were collected and are being analysed for various constituents. GEOtop model was setup for modelling of permafrost characteristics and Topographic Wetness Index (TWI) map, Emissivity map, PISR map, LST map, etc. have been prepared. In first step evaluation, ERA5 data has been evaluated with meteorological data from AWS at NIH field station (2015-2017). In second step evaluation, LST need to be correlated with GST sensor data from the field. Samples were collected from various horizons, except permafrost (due to non-availability of ice corer); the collected samples were analysed for Carbon and Nitrogen. Samples were collected from various horizons, snow, glacier, stream water, ground water, aufeis and supra-permafrost; and the collected samples of 2020-21 were analysed for ^{18}O and D and the results used as end members to find the interrelationship. The analysis of 2022 samples in progress. It will take about a year's time, to estimate various pools to the stream runoff. A stakeholders' workshop will also be held in Leh, Ladakh.

The Chairman queried whether any GPR measurements to measure depth to permafrost horizon have been carried out? PGJ replied that some manual excavation work has been done by Kashmir University. However, in the absence of ice corer, direct depth measurements were not performed to assess the depth of permafrost, nor was GPR available with the project team. In the next project team meeting, feasibility of GPR survey for select locations will be explored.

Approved Work Program for the Year 2023-24 (<u>On-going Studies)</u>

1 Estimation of changes in snow cover and Climate-Cryosphere linkages for Upper Chenab River Basin

- Validation of the mass balance of select glaciers in U. Chenab Basin.
- Investigation of climate-cryosphere linkages in U. Chenab Basin.

2 Early Signatures of 21st Century on Snow Cover Dynamics in Zanskar River Basin, Ladakh

- Investigation of the impact of climate change on snow cover extent

3 Investigation of Hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scares Western Himalayan River basin

- Set up 2D diffusion wave-based Rainfall-Runoff Inundation (RRI) model for the study basin.

4 Mass Balance of Phuche and Khardung glaciers, Ladakh Range with implications for downstream water availability under changing climate.

- Winter, Summer and Annual Mass Balances of Phuche and Khardung glaciers
- Meteorological and Hydrological data collection and analysis

5 Comparative Analysis of Fine Scale Satellite & Reanalysis Precipitation Products in Upper Ganga Basin using Multi-Criterion Decision-Making

- Completion of Statistical analysis and performance ranking

6 Permafrost mapping and characterization of Western Himalayan Region

- Field work for data retrieval and sample collection in Leh District, Ladakh.
- Finalization of GEOtop modelling results on the basis of which, permafrost characteristics such as active layer thickness, surface and thermal offset, mean annual ground temperatures will be simulated at the selected sites.
- Preparation of spatial distribution map of permafrost for the study area.
- The interpretation of datasets in terms of biogeochemical dynamics of permafrost regions.
- Stakeholders Workshop in Leh, Ladakh

Approved work program for the year 2023-24

S. No.	Title of Study	Team	Duration	Remarks
Internal Studies				
1.	Estimation of changes in snow cover and climate-cryosphere interaction in Upper Chenab River Basin	P. G. Jose D. S. Bisht	02 Years 07 months (Aug. 2020 – Mar. 2023)	Ongoing, Extn. up to Oct. 2023
2.	Early signatures of 21st Century on snow cover dynamics in Zanskar River Basin, Ladakh	D. S. Bisht P. G. Jose	02 Years (July 2021 - June 2023)	Ongoing. Extn. up to Dec. 2023
3.	Investigation of hydrodynamic approach of flood inundation mapping and assessment of changes in river planforms using a cloud-based GEE platform in data-scarce Western Himalayan basin	R. V. Kale A. K. Lohani J. P. Patra D. Khurana	03 Years (Sept. 2021- July 2024)	Ongoing
4.	Mass balance of Phuche and Khardung glaciers, Ladakh Range with implications for downstream water availability under changing climate.	P. G. Jose D. S. Bisht D. Khurana	03 Years (July 2021- June 2024)	Ongoing
5.	Comparative analysis of fine-scale satellite & reanalysis precipitation products in Upper Ganga Basin using multi-criterion decision-making	D. S. Bisht M. K. Goel	01 Year (June 2022 – May 2023)	Ongoing. Extn. up to Dec. 2023
Externally funded R & D Studies				
1.	Permafrost mapping and characterization of Western Himalayan Region	P. G. Jose A.P. Dimri (JNU) G. Jeelani (KU) V. Agnihotri (GBPNIHESD)	04 years (Aug 2019- Mar 2024)	Ongoing study funded under NMHS.

CENTRAL INDIA HYDROLOGY REGIONAL CENTRE BHOPAL

Scientific Manpower

S N	Name	Designation
1	Mr. R V Galkate	Scientist F & Head
2	Dr. T. Thomas	Scientist F
3	Mr. R K Jaiswal	Scientist E
4	Mrs. Shashi P.Indwar	Scientist D
5	Sh. Rahul Kumar	RA

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आपो हि ष्ठा मयोभुवः

Approved Work Program for the year 2022-23

S N	Title of Project/Study	Study Team	Duration	Status & Comments/ suggestions	Funding
Internal Studies					
1.	An experimental assessment of low-cost Auger Hole Technique for accelerating groundwater recharge	**NIH** R.V. Galkate R.K. Jaiswal **MP-WALMI** Vivek Bhatt	2 years (Sept 2020 – August 2022)	Ongoing In-progress in collaboration with WALMI Bhopal	Internal
2.	Re-assessment of evapotranspiration (*ETo*) estimation for irrigation planning in Madhya Pradesh	**NIH** R.V. Galkate R.K. Jaiswal A.K. Lohani Shashi Indwar **MP-WRD, Bhopal** Deepak Satpute Sayyam Jhanjari Sameer Soni	3 years (Nov 2021 – Oct 2024)	Ongoing In-progress in collaboration with BODHI, MPWRD Bhopal	Internal
3.	Water Availability Assessment for Project Formulation in Sub Basins of Ganga River in Madhya Pradesh	**NIH** R K Jaiswal, Ravi Galkate A K Lohani **MP-WRD, Bhopal** B Baghel	3 years (Nov 2021 – Oct 2024)	On-going	Internal
4.	Development of Reservoir Operation Plan under Climate Change scenarios for Kolar reservoir	**NIH** Shashi Indwar T. Thomas R. K. Jaiswal R.V. Galkate **MP-WRD, Bhopal** C.E, Hoshangaba, S.E Kolar E.E Kolar.	3 years (Oct 2021 – Sept 2024)	On-going	Internal
Sponsored Projects					
5.	Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh	**NIH** T. Thomas, B. Venkatesh R.V. Galkate Shashi Indwar R. K. Jaiswal P. C. Nayak Surjeet Singh **MP-WRD, Bhopal** Director Hydromet Mahesh Paliwal B. Baghel.	4 years (Dec 2017- July 2022)	Ongoing	PDS under NHP
6.	Integrated Assessment of the Impacts of Climate Change and Land-use Change on the Hydrology of the Narmada basin through	**NIH** T. Thomas, B. Venkatesh P. C. Nayak Surjeet Singh	5 years (Feb 2018 – Sep 2023)	Ongoing	Special PDS under NHP

	Hydrological Modelling Approaches	Shashi Indwar **MP-WRD, Bhopal** Director Hydromet Mahesh Paliwal, B. Baghel.			
7.	Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Sanjay Sagar Project in Madhya Pradesh	**NIH** R K Jaiswal Ravi Galkate T Thomas Shashi Indwar A K Lohani Sudheer Kumar Surjeet Singh **MP-WRD, Bhopal** Director, Hydromet, SE, GW circle, Database Admin, SE, EE, and AEs of Bah Project	4 years (Apr 2019 – Sept 2023)	Ongoing	PDS under NHP
8.	Development of Decision Tool for Efficient Utilization of Water Resource in Parbati Canal Irrigation Project of Rajasthan:	**NIH** R K Jaiswal, Ravi Galkate Shashi Indwar A K Lohani **WRD Rajasthan** Shailendra Kumar Sanjay Agrawal C B Garg	3 years (Apr 2019- March 2022) *(Granted Extension up to Sept 2022 by NPMU due to Corona reason)*	On-going	PDS under NHP
9.	Integrated reservoir operation studies for Mahanadi reservoir project complex in Chhattisgarh: SP-56/2021-22/NIH (CIHRC)	**NIH** R K Jaiswal, Ravi Galkate Shashi Indwar A. K. Lohani M. K. Goel, Vishal Singh Sumit Saini Dipti Rani **WRD Chhattisgarh** A. Verma, J. K. Das, V. K. Dubey A. Gupta, P. Awadhiya, **IGKV Raipur** S. Chandinah	2 years (Apr 2022-Mar 2024)	New Study	SP under NHP

RecommendedWork Program for the year 2023-24

SN	Title of Project/Study	Study Team	Duration	Status / Comments	Funding
Internal Studies					
1.	Re-assessment of evapotranspiration (*ETo*) estimation for irrigation planning in Madhya Pradesh	**NIH** Sh. R.V. Galkate, Dr. R.K. Jaiswal Dr. A.K. Lohani Ms. Shashi Indwar **MP-WRD, Bhopal** Sh. Deepak Satpute Sh. Sayyam Jhanjari Sh. Sameer Soni	3 years (Nov 2021 – Oct 2024)	Ongoing	Internal
2.	Water Availability Assessment for Project Formulation in Sub Basins of Ganga River in Madhya Pradesh	**NIH** Dr. R K Jaiswal, Sri Ravi Galkate, Dr. A K Lohani. **MP-WRD, Bhopal** Dr. B Baghel	3 years (Nov 2021 – Oct 2024)	On-going	Internal
3.	Development of Reservoir Operation Plan under Climate Change scenarios for Kolar reservoir	**NIH** Ms. Shashi Indwar, Dr. T. Thomas, Dr. R. K. Jaiswal, Sh. R.V. Galkate, **MP-WRD, Bhopal** C.E, Hoshangabad, S.E Kolar, E.E Kolar.	3 years (Oct 2021 – Sept 2024)	On-going	Internal
Sponsored Projects					
4.	Integrated Assessment of the Impacts of Climate Change and Land-use Change on the Hydrology of the Narmada basin through Hydrological Modelling Approaches	**NIH** Dr. T. Thomas, Dr. B. Venkatesh, Dr. P. C. Nayak, Dr. Surjeet Singh, Ms. Shashi Indwar **MP-WRD, Bhopal** Director Hydromet Sh. Mahesh Paliwal, Dr. B. Baghel.	5 years (Feb 2018 – Sep 2023)	Ongoing	Special PDS under NHP
5.	Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Sanjay Sagar Project in Madhya Pradesh	**NIH** Dr R K Jaiswal, Sh. Ravi Galkate, Dr. T Thomas Ms. Shashi Indwar, Dr. A K Lohani, Dr Sudheer Kumar, Dr Surjeet Singh **MP-WRD, Bhopal** Director, Hydromet, SE, GW circle, Database Admin, SE, EE, and AEs of Bah Project	4 years (Apr 2019 – Sept 2023)	Ongoing	PDS under NHP

6.	Integrated reservoir operation studies for Mahanadi reservoir project complex in Chhattisgarh: SP-56/2021-22/NIH (CIHRC)	**NIH** Dr R K Jaiswal, Sri Ravi Galkate, Mrs. Shashi Indwar Dr. A. K. Lohani, Dr. M. K. Goel, Dr. Vishal Singh, Sh. Sumit Saini, Ms. Dipti Rani. **WRD Chhattisgarh** Sh. A. Verma, Sh. J. K. Das, Sh. V. K. Dubey, Ms. A. Gupta, Sh P. Awadhiya, **IGKV Raipur** Dr. S. Chandinah,	2 years (Apr 2022-Mar 2024)	Ongoing	Special Project under NHP
7.	Assessment of impact of climate change on water resources in Shipra river basin	**NIH, Bhopal** Dr. Ravi Galkate, Dr. R. K. Jaiswal, Er. Shashi Indwar, **RNTU, Bhopal** Dr. Shalini Yadav, Dr. S. K. Sharma	3 years from the date of award	In principle approval by INCCC and final letter of award	INCCC, M/o Jal Shakti
8.	Water Resource Management for Tawa Reservoir Project under Climate Change	**NIH, Bhopal** Dr. R. K. Jaiswal, Dr. Ravi Galkate, Er. Shashi Indwar, **MPU Bhopal** Dr.R N Yadav, Dr.M P Verma	3 years from the date of award	In principle approval by INCCC and final letter of award	INCCC, M/o Jal Shakti

Progress of the studies undertaken during the year 2022-23

1. Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh (PDS)

Dr. T. Thomas, P.I. presented the progress of the PDS for Chambal basin in Madhya Pradesh and informed that SWAT has been set up from the Chambal basin up to the Sawai Madhopur GD site and with dams incorporated in the model. The analysis indicated that the high flows are projected to increase in the future whereas the low flows are projected to decrease in the future. A drought vulnerability assessment were carried out for the baseline (1961-90), present (1991-2015), near-term (2021-2040), mid-term (2041-2070), and end-term (2071-2100) time zones which varies from slight to moderate. The desertification vulnerability is projected to be less in the future as compared to the baseline period. The climate vulnerability assessment is projected to be much higher in the future as compared to the baseline period. An integrated vulnerability assessment framework has been developed by integrating the drought, desertification, and climate vulnerability. Dr. Sudhir Kumar, Director NIH has enquired about how the groundwater drought is defined in the work and Dr. Thomas explained that Groundwater Drought Index (GDI) has been used for the groundwater drought characteristics. He also suggested identifying a few GCMs that are more suited to the study area. The Chairman asked the PI to give few suggestions to mitigate the impacts of climate change to the policy makers. In response to a query from Sh. D. S. Rathore, Sc-F (Retd.), NIH, Dr. Thomas mentioned that that the trends were removed from the auto-correlated time series before performing the analysis for detection of trends.

2. Integrated Assessment of the Impacts of Climate Change on the Hydrology of the Narmada basin through Hydrological Modelling Approaches (Spl. PDS)

Dr. T. Thomas, P.I. presented the progress of the Special PDS for the Upper Narmada basin up to Hoshangabad. He informed that the CMIP6 data for SSP245 and SSP585 scenarios have been used for modeling. Extreme rainfall and extreme temperatures are projected to increase in the near term (2021-2040), mid-term (2041-2070), and long-term (2071-2080). As per the hydrological modeling of surface water carried out using SWAT, VIC, WEAP, HEC-HMS, and MIKE11-NAM model simulations, the high flows are expected to increase in the future, while low flows are expected to decrease in the future. The groundwater flow modeling carried out using the MODFLOW and WETSPASS model indicated that the groundwater recharge is projected to increase in the future under the SSP245 scenario. The PI presented results of the reservoir operation using NIH_ReSyp for Barna dam; the analysis for drought characteristics including drought frequency and severity, for the various tributaries of river Narmada in Upper Narmada under future climate scenarios. Dr. Sudhir Kumar, Director NIH, asked the PI whether the remaining works be completed in the allotted duration for the project. Dr. Thomas informed that the extension will be sought for completing the remaining analysis related to flood modeling for which the project staff recruitment is underway.

3. Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Sanjay Sagar Project in MP (PDS)

Dr. R. K. Jaiswal, P.I. presented the progress of the PDS and explained that the NAM model for the Bah G/D site was used and the results of soil testing in the command were used for the setup of MIKE HYDRO basin model for reservoir operation and planning. He informed about the development of an Excel based dashboard for irrigation management where future forecast data can be used to determine demand and deficit in advance. In this dashboard by giving information on cropping areas, reservoir level at the start of the canal, the demand and deficit in different WUAs can be computed. He explained about development of web/mobile application for communication between farmers and WR managers. Different features of web/mobile application were explained where farmers get information of water availability in reservoir and can raise their complaints regarding canal breach or not getting water to WR managers. Dr. A. K. Lohani, Coordinator RC Bhopal, has asked to conduct mass awareness programs in the study region. Dr. Sudhir Kumar, Director NIH asked that what are the final results on irrigation water return flow and which are the best models to assess the return flow. Sh. M. W. Paunikar, Director, CWC Bhopal, has suggested that the return flow analysis has to be done on the monthly basis and how this tool is being utilized by the farmers and enquired as to who is the administrator. Dr. Jaiswal informed that at present, NIH is the administrator and later on it shall be transferred to the concerned State agency. Dr. T. R. Nayak, Member (Civil) NCA, has requested that the return flow need to be quantified for the commands of Tawa and Omkareshwar projects.

4. Re-assessment of evapotranspiration (ETo) estimation for irrigation planning in Madhya Pradesh

Dr. Ravi Galkate, P.I. presented the progress of the ongoing study. He informed that in Madhya Pradesh, WRD estimates the irrigation water requirement using the guideline given in Technical Circular 25 (TC-25), which generally overestimates the reference evapotranspiration (ET_o). He explained the Penman-Monteith method shall be used to compute the ET_o in the present study. Dr. Sudhir Kumar, Director NIH, mentioned that the estimation of ET_o needs to be re-checked and also suggested that the online available tools may also be tested for estimation of ET_o. He also suggested estimating the ET_o for the different agro-climatic zones of Madhya Pradesh.

5. Water Availability Assessment for Project Formulation in Sub Basins of Ganga River in Madhya Pradesh

Dr. R. K. Jaiswal, PI informed the study area includes various subbasins of Ganga river system. He informed that the rainfall and runoff data of MPWRD have been analyzed. A GIS database of G/D sites of WRD MP was prepared by correcting the location for improvement in the website of WRD MP. A GEE-based SCS-CN model was implemented for Bah, Shipra, and Bina River basins. Dr. Jaiswal presented the study briefly and explained the methodology with results. The Chairman suggested having a relook into the developed rainfall-runoff relationships. Dr. A.K. Lohani suggested considering the base flow aspects also in the study.

6. Development of Decision Support Tool for Efficient Utilization of Water Resource in Parbati Canal & Dholpur Piped Irrigation Project of Rajasthan (PDS Under NHP)

Dr. R. K. Jaiswal, P.I. informed that the study is based on a methodology similar to the study on return flows presented earlier. Due to time constraint, the study could not be presented in detail, however, PI highlighted the progress and main outcomes of the study.

7. An experimental assessment of low-cost Auger Hole Technique for accelerating ground water recharge

The study has been completed and the report has been submitted. The study could not be presented due to lack of time.

8. Integrated Reservoir Operation studies for Mahanadi Reservoir Project Complex in Chhattisgarh

Dr. R K. Jaiswal informed the members that the study is progressing as planned. However, the study could not be presented due to lack of time.

9. Development of Reservoir Operation Plan under climate change scenarios for Kolar reservoir.

The study could not be presented due to lack of time. Moreover, Ms. Shashi P. Indwar, P.I. was on a long leave since the last few months.

DELTAIC REGIONAL CENTRE KAKINADA

Scientific Manpower

S N	Name	Designation
1	Dr. YRS Rao	Scientist G & Head
2	Dr. V S Jayakanthan	Scientist F
3	Mr. R. Venkata Ramana	Scientist E
4	Sh.Sabyasachi Swain	Scientist B
5	Sh. P R S Rao	SRA
6	Sh. Anil Kumar	RA

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REVIEW OF WORK PROGRAMME FOR THE YEAR 2022 – 2023.

S.N.	Project	Study Team	Status & Comments /Suggestions
I. Internal Project (ongoing)			
01.	Identification of Recharge and Discharge areas of Palar river basin in Tamil Nadu	V.S. Jeyakanthan (PI) Sudhir Kumar Y.R.Satyaji Rao R.Venkata Ramana	1. Chairman suggested to collect rainwater samples within the basin for stable isotope analysis and extended for one more year. 2. Prof. Madhavi suggested to include the lithology of the study area to improve the accuracy of the results. 3. Dr Sarangi suggested to identify recharge sites based on morphometric analysis which includes calculation of stream length ratio, drainage density, length of overland flow etc. 4. Dr Raju suggested to plot hypsometric curve of the basin and to include hydrological analysis. Further he suggested to refer the NRSC maps developed under Rajiv Gandhi drinking water mission. ***RCC recommended to extend the project for one year, i.e., till March 2024***.
02.	Impact assessment of backwater through drains, creeks and river mouths on groundwater salinity in the Godavari Delta, Andhra Pradesh	Y.R. Satyaji Rao (PI) Sudhir Kumar V.S.Jeyakanthan R.Venkata Ramana	Dr. Sarangi suggested to apply a 1-D unsaturated model to study the vertical leaching of salinity. He also suggested for MoU for collaborative studies on irrigation drainage/water logging. ***RCC recommended continuation of the study.***
II. Sponsored Projects			
03	Urban hydrological studies of critical pilot area using of hydrological instruments in the Greater Hyderabad Municipal Corporation (GHMC) area Hyderabad	R.Venkata Ramana (PI) Y.R. Satyaji Rao V.S. Jeyakanthan T.Vijay	Dr Sarangi suggested to compare average rainfall through Theissen polygon and semi-variogram techniques. He also suggested to incorporate IoT/mobile applications in future studies. Dr Raju suggested to incorporate model application real time forecasting using IMD rainfall forecast. ***RCC recommended the completion of study with the remark that the above comments are incorporated in the final report.***
04.	High performance Advanced Septic	Y.R.Satyaji Rao (PI) T.Vijay	Dr Sarangi suggested to implement same technology with different MLS bricks and

	System for Villages and Roadside Restaurants		different thickness of layers elsewhere. ***RCC recommended the continuation of the study.***
05	Quantification of SGD and its quality flux along the north coastal Andhra Pradesh	Y.R. Satyaji Rao (PI) Sudhir Kumar, S.M Pingale, M.K.Sharma R.Venkata Ramana	Project yet to be awarded by MoES.

APPROVED WORK PROGRAMME FOR THE YEAR 2023 – 2024

S.No.	Title of the Project	Team	Duration (Start Date – End Date)	Funding
I. Internal Project (Ongoing)				
1	Identification of Recharge and Discharge areas of Palar river basin in Tamil Nadu	V.S. Jeyakanthan (PI) Sudhir Kumar Y.R.Satyaji Rao R.Venkata Ramana	3 years (09/21 - 03/24)	Internal Funding (NIH)
2	Impact assessment of backwater through drains, creeks and river mouths on groundwater salinity in the Godavari Delta, Andhra Pradesh	Y.R.Satyaji Rao (PI) Sudhir Kumar V.S.Jeyakanthan R.Venkata Ramana	2 years (08/22 – 07/24)	Internal Funding (NIH)
II. Internal Projects (New)				
3	Storm water flood Management in the coastal city - A case study	R.Venkata Ramana (PI) Y R Satyaji Rao (PI) V. S. Jeyakanthan Sabyasachi Swain	2 years (04/23 – 03/25)	Internal Funding (NIH)
4	Climate Change Impact Assessment under Future Scenarios over the East Coast of India: A focus on the Hydroclimatic Extremes	Sabyasachi Swain (PI) Y.R. Satyaji Rao V.S.Jeyakanthan R Venkata Ramana	2 years (04/23 – 03/25)	Internal Funding (NIH)
5	Evaluation and post-processing of multi-model short-to-medium-range precipitation forecasts: Towards developing a flood early warning system over Subarnarekha Basin	Sabyasachi Swain (PI) Y.R. Satyaji Rao Biswajeet Pradhan Saswata Nandi	3 years (04/23 – 03/26)	Internal Funding (NIH)
III. Sponsored Project (Ongoing)				
6	High Performance Advanced Septic System for Villages and Roadside Restaurants	Y.R. Satyaji Rao (PI)	5 Years (04/18 –12/23)	IC- IMPACT Canada

The proposals for new studies were presented and deliberated in detail. Comments and recommendations of the RCC members on each study are given below:

S. No.	Title of the Project	Team	Duration	Status & Comments /Suggestions
Internal Projects (New)				
1	Sedimentation assessment of Rengali Reservoir, Odisha using Optic and Microwave Remote Sensing Technology	V.S.Jeyakanthan (PI) Y R Satyaji Rao R.Venkata Ramana	2 years (04/23 – 03/25)	***After detailed discussion, RCC did not recommend the study***
2	Storm water flood Management in the coastal city - A case study	R.Venkata Ramana (PI) Y R Satyaji Rao (PI) V. S. Jeyakanthan Sabyasachi Swain	2 years (04/23 – 03/25)	Dr. Raju suggested to change the name of the study as *Storm water flood Management in the coastal city - A case study* and also suggested to incorporate suitable methodology with sea boundaries/tides. ***RCC recommended the proposed study***.
3	Climate Change Impact Assessment under Future Scenarios over the East Coast of India: A focus on the Hydroclimatic Extremes	Sabyasachi Swain (PI) Y.R. Satyaji Rao V.S.Jeyakanthan R Venkata Ramana	2 years (04/23 – 03/25)	1. Dr. Sarangi suggested to streamline the objectives and make them more focussed. He further suggested to use non-parametric methods to assess various characteristics of historical and future periods. 2. Dr. Raju recommended to restrict the spatial extent of the study from entire east coast to a river basin in the Est Coast. 3. Dr. Basant Jena and Dr. H.R. Biswas suggested that although the study of precipitation, temperature and heatwaves can be carried out at the entire east coast, analyzing future water availability under climate change over a particular basin shall be worthwhile. 4. Sri Lingaraj Gouda expressed his opinion that if the study could consider a catchment of Odisha and provide its flow availability or flood conditions in the future, that can be highly useful. ***RCC approved the study in principle with the revised objectives addressing the concerns of the committee with a special focus on flood conditions over a catchment in the deltaic region in future.***
4	Evaluation and post-processing of multi-model short-to-medium-range precipitation forecasts: Towards developing a flood early warning system over Subarnarekha Basin	Sabyasachi Swain (PI) Y.R. Satyaji Rao Biswajeet Pradhan Saswata Nandi	3 years (04/23 – 03/26)	1. Dr. Raju suggested the Subarnarekha catchment with minimal flow regulating structures is suitable for this study. 2. Dr. Biswas emphasized that the bias correction of the TIGGE ensemble precipitation forecasts should be done carefully. ***RCC recommended the proposed study***.

NORTH EASTERN REGIONAL CENTRE GUWAHATI

Scientific Manpower

S N	Name	Designation
1	Dr. S V Vijaya Kumar	Scientist G & Head
2	Dr. S K Sharma	Scientist D
3	Dr. Swapnali Barman	Scientist D
4	Dr. Waikhom Rahul Singh	Scientist C
5	Sh. Siddhartha Arora	Scientist B
6	Sh. Hakim Singh Meena	RA

APPROVED WORK PROGRAMME FOR THE YEAR 2022-23

Sl. No.	Title	Study Group	Duration (Month/Year)	Study Type	Remarks
1.	Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin	*Gulshan Tirkey, S. K. Sharma, P. Mani	#3 years (4/18 to 3/21)	Internal	*PI to be Dr. W. R. Singh #To be taken up as new study in 2023-24
2.	Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya	*G. Tirkey, S. K. Sharma, A. K. Lohani	#2 years (9/20-8/22)	Internal	*PI to be Dr. S.K. Sharma #To be taken up as new study in 2023-24
3.	River basin planning and reservoir operation studies in Teesta basin up to confluence with Rangit River in Sikkim	Swapnali Barman M.K. Goel A.K. Lohani D.S. Rathore, Deepti Rani W.R. Singh	3 years (9/19 to 4/23)	Sponsored under NHP	Completed
4.	Study on Behaviors of Flooding and Unexpected Drought like Situations in Garo Hills District of Meghalaya	S. K. Sharma R.P. Pandey GulshanTirkey Swapnali Barman W.R. Singh	3 years (9/19 to 4/23)	Sponsored under NHP	Completed
5.	A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World	Swapnali Barman, R.K. Bhattacharya M.K. Dutta, W.R. Singh	3 Years (4/21-3/24)	Sponsored under DST-SERB Powergrant	On-going
6.	Impact of Climate Change on Flood Inundation in Beki River Basin	S.K. Sharma, S.Barman, W.R. Singh, S.V. Vijaya Kumar	1 year (7/22-6/23)	Internal	Completed
7.	Drought characterization and vulnerability assessment in Assam	W.R. Singh, S.Barman, S.K. Sharma, S.V. Vijaya Kumar, A.K. Lohani	2 years (7/22-6/24)	Internal	On-going

RECOMMENDED WORK PROGRAMME 2023-24

Sl. No.	Title	Study Group	Duration (Month/Year)	Study Type	Remarks
1	A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World	S Barman, R.K Bhattarcharjya, M.K. Dutta W.R. Singh	3 years (04/21-03/24)	Sponsored Under DST-SERB (Power Grant)	On-going
2.	Drought characterization and vulnerability assessment in Assam	WR Singh, S Barman, SK Sharma, SV Vijaya Kumar, AK Lohani	2 Years (7/22 – 6/24)	Internal	On-going
3	Short Term Flood Forecasting Using Bootstrap based Artificial Neural Networks within Beki River basin.	S.K. Sharma, S. Barman, S. Arora, S.V. Vijaya Kumar, A.K. Lohani	1 Year (7/23 – 6/24)	Internal	New study
4.	Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin	W. R. Singh Swapnali Barman, S. Arora, S.V. Vijaya Kumar,	1.5 years (9/23-2/25)	Internal	New study
5	Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya	S. K. Sharma S. Barman, S. Arora, S. V. Vijaya Kumar,	1.5 years (9/23-2/25)	Internal	New study
6	Hydrodynamic modelling for riverbank protection- A case study	Swapnali Barman, W. R. Singh, S Arora, S. K. Sharma S. V. Vijaya Kumar	1.5 years (9/23-2/25)	Internal	New study

REVIEW OF THE WORK PROGRAM FOR THE YEAR 2022-23

1. River basin planning studies in Teesta basin up to confluence with Rangit River in Sikkim

Dr. Swapnali Barman, PI of the project presented the completion report. Dr. Diganta Barman applauded the work done by the study team and requested PI to share specific conclusions to be added in Water Resources Atlas which is being prepared by his team at NESAC.

2. Study on Behaviors of Flooding and Unexpected Drought like Situations in Garo Hills District of Meghalaya

Dr. S. K. Sharma presented the study. He briefly explained about the objectives, methodology and conclusions of the study. Mrs. Blah, Chief Engineer, Water Resourced Department, Meghalaya asked about the mitigation plans for drought in the region. She also said a workshop will be held to discuss the outcomes from the study. Dr. Diganta Barman, NESAC recommended to use the basis of extreme events in terms of magnitude and duration rather than based on return period for delineation of floodplains. Use of high-resolution data is also recommended. Dr. P.K. Bora, Director NERIWALM asked about the recommendations for drought in Meghalaya. Chairman directed that suggestions of the members are to be incorporated in final report.

3. Impact of Climate Change on Flood Inundation in Beki River Basin

Dr. S. K. Sharma presented the study. He briefly explained about the objectives, methodology and outcomes of the study. Dr. Diganata Barman, Head, Water Resources Department, NESAC suggested that instead of taking return period taking extreme flood events to produce flood hazard maps some extreme events need to be studied. Dr. Sudhir Kumar, Chairman RCC enquired about the validation of the climate models for which Dr. A. K. Lohani, mentioned that a set of relevant climate change models advocated are studied. Dr. S. K. Sharma replied that the RRI Model used in the study has been validated. Chairman directed that suggestions of the members are to be incorporated in final report.

4. Drought characterization and vulnerability assessment in Assam

Dr. W. R. Singh presented the progress of the study. Director, NERIWALM opined on justifications based on analysis of gridded rainfall data in such studies and also advised using evapotranspiration data in the study to better characterize drought severity. Dr. Diganta Barman, NESAC suggested to incorporate soil moisture data from sources such as ALOS PULSAR, NDMI, NDWI, etc. to add value. Chairman directed that suggestions of the members are to be incorporated in study.

5. Linear hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin

Head, NERC Guwahati informed the difficulties in taking up the study due to demise of the scientist handling the data and other information. However, stressing the importance of the study and its utility, the chairman directed that this study may be initiated as a new study by the Centre with Dr. W. R. Singh as PI.

6. Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya

Head, NERC Guwahati informed the difficulties in taking up the study due to demise of the scientist handling the data and its analysis. However, as sought by the CE, WRD, Meghalaya, Chairman directed that as the outcome of study is necessary for the state the same be initiated as new study by the Centre with Dr. S. K. Sharma as PI.

7. A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World

Dr. Swapnali Barman, presented the progress of the study. Dr. Diganta Barman suggested changing the word ‘Coupled’ in the project title to ‘Hybrid’ to reflect the simulation models applied to address the problem. Director NEHARI, suggested to have regular discussion with agencies working in field on protection of Majuli Island. Such interaction will help orient the results of the study to relevant outcomes. Chairman supported the opinion and agreed that knowledge gained from such studies should be carried on and further studies may be taken up in future to support local agencies. Chairman directed that suggestions of the members are to be considered in the study.

PROPOSED WORK PROGRAMME FOR 2023-24

In continuation of the two ongoing studies, the following four new studies were directed to be taken up by the committee. Two studies as at sl. No 5 and 6 at item 18.4 are being taken up afresh, along with two new studies. So, the Centre will undertake six studied during 2023-24. The four new studies are as below.

1. **Linear hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin**

As opined by members stressing the importance of the study and its utility, the chairman directed that this study may be initiated as a new study by the Centre.

2. Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya

As mentioned by the CE, WRD, Meghalaya that the study is important for the state, Chairman directed that since the outcome of this study is needed for the state, the same be initiated as new study by the Centre.

3. **Short Term Flood Forecasting Using Bootstrap based Artificial Neural Networks within Beki River Basin**

Dr. S. K. Sharma, briefly explained the objectives, proposed methodology and expected outcomes of the study. Dr. S.V. Vijaya Kumar, Head, NERC, NIH Guwahati suggested to use maximum years of data for simulation in the study. There were suggestions from Dr. A. K. Lohani, Dr Diganta Barman and Shri G. L. Bansal on consideration of inflows from reservoirs that are located in Bhutan during simulation. Dr. A. K. Lohani, suggested to take up machine learning algorithms as well.

4. Hydrodynamic modelling for riverbank protection- A case study

As directed by Chairman on suggestions of members from NEHARI, Brahmaputra Board and WRD, Assam, it is proposed to carry out this modeling study to simulate riverbank erosion around bank protection measures for a proposed or ongoing scheme. The study is expected to help the stakeholders and other agencies to understand scientifically, the hydrodynamic processes of the reach and the effect of river training works in protecting the bank from erosion. It is also expected that the case study would be helpful to utilize similar analysis to other vulnerable reaches. The study will be carried out with collaboration and support on various firld information and data required for analysis and modeling, from Water Resources Department, Govt. of Assam and Brahmaputra Board as discussed at the meeting.

CENTRE FOR FLOOD MANAGEMENT STUDIES PATNA

Scientific Manpower

S N	Name	Designation
1	Dr.Pankaj Mani	Scientist G & Head
2	Dr. Pravin Rangrao Patil	Scientist C
3	Sh. Suryansh Mandloi	Scientist B
4	Sh. Uday Pratap S. Bhadoriya	Scientist B
5	Sh. Shubham Shaurabh	Scientist C
6	Sh. Atam Prakash	SRA
7	Sh. Asif	RA

The progress of the studies listed in work program of the year 2022-23 was presented by the PI of the respective studies. The summary of the discussions held during the RCC meeting are given below.

SN	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/ Suggestions
	Internal Studies	
1.	Study of flood mitigation measures in Mahav nala using mathematical modelling study **Study Group:** Pankaj Mani (PI) J. P. Patra B. Chakravorty, Ex-Scientist with support from UP Irrigation Department (UPID) and Forest Department (Maharajganj) **DOS:** April 2022 **DOC:** March 2023	The study was presented by Dr. P. Mani. He informed that design flood is estimated for Mahav nala based on CWC PMP atlas and computed as 187 m^3/s. The carrying capacity of Mahav nala with existing cross sections is computed as 10 m^3/s. The design section of Mahav nala is computed for design flood as (i) Flow depth = 4m (ii) Side slope = 1:1 (iii) Bottom width = 22 m and (iv) Longitudinal slope = 0.0004 m/m The CGWB member wanted to know whether the silt can be trapped in the upstream reaches or not, Dr. Mani replied that the upper reaches lies under the territory of Nepal, where UPID has no control.
2.	Design flood estimation for small structures in the South Bihar area. **Study Group:** Pankaj Mani (PI) J. P. Patra B Chakravorty, Ex-Scientist Pravin Rangrao Patil, I C Thakur, Director WALMI **DOS:** April 2021 **DOC:** September 2023	The progress of study was presented by Dr. P. Mani. Dr. Mani informed that due to breakdown of computer system the progress of study is delayed. He requested for some more time to complete the study. The Chairman agreed to extend the study till September 2023.
3.	Integrated Flood Management Plan for a stretch of Burhi Gandak River from Sikanderpur to Rosera. **Study Group:** B Chakravorty (PI) Ex-Scientist, Pankaj Mani, Suryansh Mandloi, N. G. Pandey, Ex-Scientist **DOS:** April 2020 **DOC:** September 2022	The study was presented by Er. Suryansh Mandloi. He informed that, the study computes the design flood by flood frequency analysis and analyzes the efficacy of the embankment in the stretch between Sikanderpur to Rosera. The model computes the level of the embankment for the design flood of 50 and 100 years. Dr. Sanjay Jain asked to send the report to reviewer.
	Sponsored Study (PDS/NHP)	
4.	Modeling and management of erosion and sedimentation processes in a reach of Gandak river using morphodynamic	The progress of study was presented by Dr. P. Mani. He explained the field activities carried out during Jun-Oct 2022 for hydrological data collection at Baligaon site. He further demonstrated the working of real time water level data

SN	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/ Suggestions
	modeling **Study Group:** Pankaj Mani(PI) J. P. Patra B. Chakravorty, Ex-Scientist & WRD Bihar **DOS:** May 2021 **DOC:** April 2024	acquisition system installed at Baligaon and Fatehabad site. Sri. P. K. Jha suggested to interact with WRD official. The Chairman suggested to study the pattern of annual peak variability and its causes. Dr. Sanjay Jain advised to study rainfall-runoff process of the basin.
Discussion on Proposed Studies for 2023-24		
5.	Influence of Non-Stationarity on Flood Frequency Analysis of South-Bihar Region **Study Group:** Pravin Rangrao Patil (PI), Pankaj Mani, Suryansh Mandloi **DOS:** May 2023 **DOC:** March 2025	The study proposal was presented by Dr. Pravin Rangrao Patil. Dr. Sanjay Jain suggested to involve a scientist from NIH HQ in the Study Group. Prof. Dilip Kumar, Professor WALMI suggested to study the water availability of the rivers of South-Bihar region.
6.	Evaluation of hydrologic models for Gandak river basin **Study Group:** Suryansh Mandloi (PI), Pankaj Mani, Pravin Rangrao Patil **DOS:** May 2023 **DOC:** March 2025	The study proposal was presented by Er. Suryansh Mandloi. Dr. Sanjay Jain suggested to incorporate a Scientist from NIH HQ in the Study Group. Sri. M. K. Singh also suggested to involve CWC officials in the proposed study. The Chairman and Prof. V. Singh suggested to identify the physical parameter those are affecting model performance.

The Chairman advised all the scientist of the center to compile a book on 'Hydrology of South Bihar' as well as to create a data repository of available data.

WORK PROGRAMME FOR THE YEAR 2023-24

The work program for the year 2023-24 was finalized during the meeting as given in the table below. One internal study and one study (PDS) under NHP are ongoing studies. Two new studies are proposed.

Sl	Title	Study Team	Duration
Internal Study			
1	Design flood estimation for small structures in the South Bihar area.	Pankaj Mani (PI), J P Patra, Pravin Rangrao Patil & Director WALMI	2 years (04/21-09/23)
Sponsored Study (PDS/NHP)			
1.	Modeling and management of erosion and sedimentation processes in a reach of Gandak river using morphodynamic modeling	Pankaj Mani (PI) J P Patra, Pravin Rangrao Patil, Suryansh Mandloi & WRD Bihar	3 years (05/21-04/24)
New Studies (Proposed)			
1	Influence of non-stationarity on flood frequency analysis for South-Bihar region	Pravin Rangrao Patil (PI), Pankaj Mani, Suryansh Mandloi	02 years (05/23-03/25)
2	Evaluation of hydrologic models for Gandak river basin	Suryansh Mandloi (PI), Pankaj Mani, Pravin Rangrao Patil	02 years (05/23-03/25)

A brief discussion about the proposed studies are given below:

1 Influence of Non-Stationarity on Flood Frequency Analysis of South-Bihar Region

Dr. Pravin R. Patil presented briefly the new proposal. He described that, more intense processes of the water cycle may cause catastrophic floods in the future. As per BIS criteria, frequency based estimation of design flood is appropriate for almost all the types of hydraulic structures, excluding large and intermediate size dams. Hydraulic infrastructures designed against extreme events are based on the return period and the hydrologic risk. Conventional flood frequency analysis (FFA) used to find the same assume that the extreme events are both independent and stationary. This traditional assumption may no longer be valid due to the impact of temporal and spatial variations of precipitation and temperature with variable catchment characteristics, such as vegetation, land use and land cover, which is reflected in the flow regimes. Thus, the incorporation of climatic variability and anthropogenic factors inspired non-stationarity into hydrological frequency analysis is considered crucial for design flood estimation under uncertain and changing environment. Moreover, time-varying non-stationary models may not always be suitable and the use of additional physically-based covariates can provide better insights. The stationary model underestimates flood quantiles compared to the non-stationary models. Differences between flood estimates of stationary and the best-fit non-stationary model become more apparent (an increase of up to 75%) at larger return periods. This study would prompt local flood managers to improve the current flood management plans and reduce the flood risk. Under the above background a study entitled "Influence of Non-Stationarity on Flood Frequency Analysis of South-Bihar Region" is proposed with following specific objectives:

1. Investigate the trends to identify the presence of non-stationarity and detect breakpoints to find the location of non-stationarity in MAF series of different gauging stations in the South-Bihar region.
2. Incorporate and assess the influence of different covariates (time, annual precipitation, land use and land cover) in non-stationary models fitted to MAF series.
3. Determine the best fit non-stationary model for efficient flood frequency analysis and compare its results with the stationary model.
4. Compare the flood quantiles and their return periods estimated using stationary and non-stationary models.

2 Evaluation of Hydrologic Models for Gandak River Basin

Er. Suryansh Mandloi presented briefly the new proposal. He described that, river basin hydrology involves complex processes such as precipitation, infiltration, interflow, runoff, groundwater flow, evaporation etc. which determines the status of streams, rivers, aquifers, lakes and wetlands. Hydrological response of catchment also depends upon terrain and meteorological conditions. Study of full spectrum of hydrological processes is essential to understand river's current condition in quantification of flows. In order to capture the river response under real world conditions both hydrologic and hydraulic processes become crucial. Use of hydrologic and hydraulic modelling tools for recognizing the movement of water through a catchment system have been provided better results in different catchments of the world. However, in the view of the complexities involved in different watersheds are not similar, it becomes necessary to check which model would be suitable for the river basin under consideration. The proposed study is focusing on the Gandak river basin and will compare the outcomes of multiple well calibrated and validated models for the basin. Under the above background a study entitled "Evaluation of hydrologic models for Gandak river basin" is proposed with following specific objectives:

1. To develop multiple hydrologic models using HEC-HMS, SWAT and MIKE Hydro Basin for inter-comparison of flows for Gandak river basin
2. Evaluation of model performance with respect to observed discharge and water level data for Gandak river at their respective CWC GD sites

APPENDIX 77.4.2

LIST OF PAPERS PUBLISHED/ ACCEPTED FOR PUBLICATION DURING APRIL 2022 – MARCH 2023 & APRIL 2023 – AUGUST 2023

LIST OF PAPERS PUBLISHED DURIG 2022-23

S.No.	Item	Published 2022-23	Published 2023-24
1.	International Journal	79	24
2.	National Journal	12	03
3.	International Conference/ Seminar/ Symposium	107	08
4.	National Conference/ Seminar/ Symposium	16	00
5.	Books/Chapters	47	10
	Total	**261**	**45**

	BOOKS
1.	Chandniha, S.K., Lohani, A.K., Krishan, G. and Prabhakar, A.K. (2022).Advances in Hydrology and Climate Change- Historical trends and new approaches in water resources management. Apple Academic Press.
2.	Pilli, S., Bhunia, P., Tyagi, V., Tyagi, R., Wong, J. and Pande, A. (2022). Current Developments in Biotechnology and Bioengineering Sustainable Treatment Technologies for Pre- and Poly-flourakyl Substances. Elsevier (UK), pp 350 (ISBN: 9780323999069).
3	Tyagi, J.V., Lohani, A.K., Arora, M., Rawat, S.S., Singh, P.K., Nema, M.K., Bisht, D.S., Uniyal, P.K., Sapra, T.R., Kumar, R., Kumar, P., Mishra, C., Kumar, N. and Guyal, V. (2022). Hydrological Knowledge in Ancient India (प्राचीन भारत में जलविज्ञानीय ज्ञान). A bi-lingual (Hindi and English) third edition of a special report published by NIH, Roorkee.
4.	Tyagi, V.K., Aboudi, K. and Eskicioglu, C. (2022).AnanerobicDigestate Management. International Water Association publishing (IWAP), pp 350 (ISBN: 9781789062).
	CHAPTERS IN BOOKS
1.	Ali, M., Pilli, S., Bhunia, P., Tyagi, R.D.,Pandey,A. and Tyagi, V.K. (2022). Occurrence, fate, and persistence of perfluorinated compounds (PFCs) in wastewater treatment systems. In: Sustainable Treatment Technologies for Per- and Poly-fluoroalkyl Substances. Currents Development in Biotechnology and Bioengineering Series. Elsevier Publishing, pp. 207-233, ISBN: 978-0-323-99906-9.
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4.	Barman, S., Tyagi, J.V. and Singh, W.R. (2023). Future Rainfall Trend Analysis Over Puthimari River Basin: A Comparative Study Using Different CMIP5 Models. In:Sustainable Water Resources Management. Advances in Sustainability Science and Technology. Springer, Singapore, pp.19-28.
5.	Bhattacharya, T., Khare, D. and Arora, M. (2020). Determination of ERA-Interim Proficiency for Rainfall Runoff Modeling. Water Science and Technology Library, Chapter, Water management and Water Governance, Springer, Cham, 96, 217-225. DOI: https://doi.org/10.1007/978-3-039-58051-3_15.
6.	Chhoden, K. and Manchanda, C.K. (2023). Ground water and Pond water Quality Assessment of District Ropar, Punjab. In: Water Science and Technology, Published by ABS Books, ISBN: 978-93-94424-62-3.
7.	Chowdhury, S.D., Tyagi, R.D.,Pilli,S.,Tyagi,V.K., Pandey,A. and Bhunia,P. (2022). Per- and poly-fluoroalkyl substances (PFASs) in water and wastewater.In: Sustainable Treatment

	Technologies for Per- and Poly-fluoroalkyl Substances. Currents Development in Biotechnology and Bioengineering Series. Elsevier Publishing. pp. 299-327, ISBN: 978-0-323-99906-9.
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9.	Dhal, L. and Swain, S. (2022). Understanding and modeling the process of seawater intrusion: a review. [Chapter 14] In: Advances in remediation techniques for polluted soils and groundwater, pp. 269-290.
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11.	Gahlot,P., Aboudi, K.,Tawfik, A. and Tyagi, V.K. (2022).Biochar-augmented anaerobic digestate treatment. In: Tyagi, V.K., Kaoutar, A., Eskicioglu, C. (Eds.) Anaerobic Digestate Management. International Water Association Publishing (IWAP). UK. pp. 265-282, Chapter 12,ISBN: 9781789062748.
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29.	Mandloi, S. (2022). Morpho-dynamic changes of Ganga River reach from Sultanganj to Bhagalpur using Remote Sensing Techniques. In: Role of Agricultural Engineering and Statistics for Sustainable Natural Resources Management, New Delhi Publishers, pp. 281-290. ISBN: 978-81-19006-28-1.
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32.	Patidar, N. and Bhagwat, A.)2022(. Data Assimilation in Groundwater Modelling. *Advances in Hydrology and Climate Change. CRC Press,* Publishing Date: July,2022.)Accepted as Ch-20(.
33.	Prabhakar, A.K., Singh, K.K., Lohani, A.K. and Chandniha, S.K. (2022). Hydrological WaterStudy in Champua Watershed of the Baitarani River Basin Using SWAT Model, Advances in Hydrology and Climate ChangeIst Edition Edited by Surendra Kumar

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61.	Nema, M.K., Mishra, P.K. andJain, S.K. (2022). Dam decommissioning: An option for India’s ageing water storage infrastructures, Presented and published in International Dam Safety Conference organized by Indian National Committee on Large Dams, India (INCOLD), CWC and CBIP at Jaipur during October 10-12, 2022.
62.	Noel, D., St. Jacques, J-M and Gurrapu, S. (2022).The effects of the Atlantic Multidecadal

	Oscillation, Pacific Decadal Oscillation, North Atlantic Oscillation and El Niño-Southern Oscillation on discharge variability in the Canadian Maritimes. AGU Fall Meeting, Chicago, USA. 12 – 16 December, 2022.
63.	Osheen, Kansal, M.L. and Bisht, D.S. (2022).Assessment of Extreme Storm Conditions for an Urban Drainage System. Inaugural International Conference on Smart and Sustainable Infrastructure organized by PDEU, Gandhinagar, India during 23-25 August 2022 at Gandhinagar (Gujarat), India.
64.	Osheen, Kansal, M.L. and Bisht, D.S. (2022).Effectiveness of LIDs in Resilience Enhancement of an Urban Drainage System: A Case Study. AGU Fall Meeting. Chicago, IL & Online Everywhere during 12-16 December 2022.
65.	Padikal, A. and Krishan, G. (2022). Mapping of groundwater salinity in Punjab, India In: Proceedings of International Groundwater Conference (IGWC-2022) Effective Management of (Sub)-Surface Water Resources in Arid and Semi-arid Regions during 02-05 November, 2022 at IIT Roorkee.
66.	Pant, A. and Bhagwat, A.)2022(. Microplastics: Quantification, identification, and its effects on aquatic invertebrates Roorkee water conclave. Held on 3-4 March, 2022.
67.	Pathak, L. and Barman, S. (2022). Runoff Simulation using SWAT Model: A Case Study for the Baralia River Watershed. International Conference on Sustainable Technologies for River Erosion Alleviation and Management (STREAM 2022) during December 14-16, 2022 organized by Department of Civil Engineering, Indian Institute of Technology Guwahati & Brahmaputra Board held at Assam Water Centre, Guwahati.
68.	Patidar, N., Krishan, G. and Sharma, A. (2022). Integrated GEE-MODFLOW Model for Groundwater Recharge Assessment. India Water Week 2022-Water security for sustainable development with equity (IWW-2022), 1-5 November, 2022 at India Expo Centre, Greater Noida.
69.	Patidar, R., Pingale, S.M., Khare, D. and Choudhary, S.)2022(. A multi-scale spatio-temporal evaluation of drought characteristics over semi-arid regions of Bundelkhand, India. Poster Session in AGU Fall Meeting held during 12-16 December, 2022 at McCormick Place in Chicago, IL, USA. https://agu2022fallmeeting-agu.ipostersessions.com/Default.aspx?s=4F-96-F8-83-A9-35-2B-EC-B4-B3-B0-12-86-16-02-D8.
70.	Patidar, R., Pingale, S.M.,Khare, D. and Dayal, D.)2022(. Spatio-temporal assessment of meteorological, hydrological, and agricultural drought over semi-arid regions of Bundelkhand, India - A multi-scale characterization. *International Conference on Climate and Weather-Related Extremes (New Dimensions, Challenges and Solutions) (ICCWE 2022)* held at IIT Roorkee during 19 & 20 September 2022. Paper Id: 7445. https://www.iitr.ac.in/iccwe2022/index.html.
71.	Patil, P.R., Chakravorty, B. and Mani, P.(2022).Soil Moisture Accounting based Sediment Transport Modeling of Storm Events of Arid Drainage Basin. Proceedings of the International Chemical Engineering Conference (IChEC) on The Role of Chemical and Allied Engineering in Environmental Protection and Green Energy organized by Dept. of Chemical & Biochemical Engineering, Indian Institute of Technology, Patna during 12-13 November, 2022 at Patna, Bihar.
72.	Patil, P.R., Chakravorty, B., Mani, P. and Mishra, S.K. (2023). First-flush Coupled SMA Inspired Modeling of Sediment Yield Events. Proceedings of theInternational Conference on Water Management and Climate Change organized by WALMI, Dharwad during 24-25 January, 2023 at Dharwad, Karnataka.
73.	Patra, J.P., Mani, P., Kumar, R., Lohani, A.K. and Gurrapu, S. (2022). Probabilistic Dam Breach Modelling of Mahi Bajaj Sagar Dam using Monte Carlo Simulation Technique in INTERNATIONAL DAM SAFETY CONFERENCE organised by Indian Committee on Large Dams (INCOLD) during 10-12th October, 2022 at Jaipur, Rajasthan.
74.	Ramana, R.V.,Jeyakanthan, V.S., Sharma, M. andRao, Y.R.S. (2023).Modeling Drainage Network in Urban Sub-Catchment of Hyderabad using SWMM. 5th Int. Nat. Conf. Recent Trends in Sci. Engg. Management (ICRTSEM - 2023), 24th March 2023 Organized by

	Karpaga Vinayaga College of Engineering and Technology, Chengalpattu, Tamilnadu, India-603308.
75.	Ramana, R.V., Sharma, M., Jeyakanthan, V.S. and Rao, Y.R.S. (2022). Spatial urban flooding map using hydrodynamic model-SWMM and HEC RAS. *International Conference on Integrated Water Resources Management Prospects and Challenges*. Organized by Karunya Institute of Technology and Sciences, Coimbatore, 08-10 December 2022.
76.	Ranade, A. (2022). Climatic changes in seasonal and extreme rainfall characteristics of seven homogenous zones of India, 9th International Groundwater conference (IGWC-2022), 2-4 Nov 2022 at IIT Roorkee.
77.	Ranade, A. (2022).Global Climatic Changes in 3-D structure of Atmospheric Temperature, International Conference on Climate and Weather –related Extremes (ICCWE-2022), 19-20 Sept 2022, IIT Roorkee.
78.	Ranade, A. (2022).Hydrometeorological Extremes across India under changing climate, Young Scientist Conference held during 22-24 January 2023 at MANIT, Bhopal as a part of India International Science Festival (IISF)-2022.
79.	Ranade, A. (2022).Long-term trend and harmonic analysis of Basin-scale rainfall across India during 1813-2020, 27th International conference on Hydraulics, Water Resources, Environmental and Coastal engineering (HYDRO-2022), 22-24 Dec 2022, Punjab Engineering College, Chandigarh.
80.	Rao, Y.R.S., Prasad, Y.S. and Kumar, S. (2022).Assessment of Salinization Processes in Shallow aquifer of Godavari Delta, India using Stable Isotopes published in the proceedings of 9th IGWC-2022, IIT Roorkee held during 02-04 November, 2022 pp. 61.
81.	Rao, Y.R.S., Prasad, Y.S., Ghosh, N.C. and Vijay, T. (2022).River Bank Filtration (RBF) – A Source for Safe Drinking Water Security published in the Proceedings of India Water Week-2022 held during 01-05, November 2022in New Delhi.
82.	Sandhu, C., Krishan, G., Grischek, T., Bornick, H., Ronghang, M., Fernandes, A.V. and Prasad, D. (2022).Need-based demonstration of riverbank filtration at sites impacted by environmental extremes in Agra and Guwahati, India In: Proceedings of International Groundwater Conference (IGWC-2022) Effective Management of (Sub)-Surface Water Resources in Arid and Semi-arid Regions during 02-05 November, 2022 at IIT Roorkee.
83.	Sharma, M., Ramana, R.V., Jeyakanthan, V.S. and Rao, Y.R.S. (2022). Spatio-temporal variations of land use/ land cover changes in urban catchment of GHMC zone.*International Conference on Integrated Water Resources Management Prospects and Challenges*. Organized by Karunya Institute of Technology and Sciences, Coimbatore, 08-10 December 2022.
84.	Sharma, M., Ramana, R.V., Jeyakanthan, V.S. andRao, Y.R.S. (2023).Developing Intensity Duration Frequency curves for Urban sub-catchment of Hyderabad City. 5th Int. Nat. Conf. Recent Trends in Sci. Engg. Management (ICRTSEM - 2023), 24th March 2023 Organized by Karpaga Vinayaga College of Engineering and Technology, Chengalpattu, Tamilnadu, India-603308.
85.	Sharma, M.K., Kumar, P., Sharma, B., Prasad, B. and Bhanot, K.(2022). Hydrochemicalbehaviour, its controlling processes and importance of p(CO2) signature of meltwater of River Bhagirathi in Upper Ganga Basin, India, Paper presented in 7th India Water Week 2022, India Expo Centre, Greater Noida during 1-5 November 2022.
86.	Sharma, P., Mishra, P.K. and Sharma, A. (2022).Integrating Multiple Land Use and Assessment of Evapotranspiration for Sustainable Management of Land and Water Resources in Upper Yamuna Basin. Proceedings of the 27th International conference on Hydraulics, Water Resources, Environmental and Coastal Engineering (HYDRO -2022), December 2022, PEC, Chandigarh.
87.	Siddik, A.B., Jaiswal, R.K., Tiwari, H.L. and Galkate, R.V. (2022).Comparative Study of Parsimonious Hydrological Models in a Sub-Catchment of Betwa River Basin. 27th International Conference on Hydraulics, water Resources Environment and Water Engg. (HYDRO 2022), organised by Punjab Engineering College, Chandigarh during 22-24 December 2022 at Chandigarh (Punjab), India.

88.	Singh, K., Singh, R., Pandey, G., Singh,S. and Malyan,S.K. (2022).Scenario of Hydrochemistry, Health risk, and Solute Source in Groundwater of Bathinda District, Punjab. In India Water Week (IWW - 2022) organized by NWDA, MoJS, GOI during Nov. 01-05, 2022.
89.	Singh, K., Singh, R., Pandey, G., Singh,S. and Malyan,S.K. (2022). Assessment of Lead in groundwater, health risk and leaching behavior from sediments of Mansa district. In: International Groundwater Conference (IGWC 2022) organized by Department of Hydrology, IIT Roorkee during Nov. 02-04, 2022.
90.	Singh, S.,Maithani, C., Malyan, S.K.,Soti, A., Kulshreshtha, N.M.,Singh, R.,Brighu, U., Gupta, A.B., Kumar, J.,Yadav, S., Singh, O. and Goyal, V.C. (2022). Comparative performance and metagenomic analysis of deep and shallow cells of a full-scale HFCW having sequentially decreasing depths reveals vast enhancement potential. International Conference on Biotechnology for Sustainable Bioresources and Bioeconomy (BSBB-2022), December 7-11, 2022, Indian Institute of Technology, Guwahati.
91.	Singh, S., Malyan, S.K., Singh, K. and Singh,R. (2022). Evaluation of Metals, Pesticides, PAHs and PCBs in groundwater of Malwa Region of Punjab, India. India Water Week (IWW-2022) organized by NWDA, MoJS, GOI during Nov. 01-05, 2022.
92.	Singh, V. (2022). Hydrological modelling using GRACE in Upper Ganga basin in the Second United Nations World Geospatial Information Congress in Hyderabad, India, from 10-14 October 2022.
93.	Singh, W.R., Barman, S., Gogoi, S. and Kalita, B. (2022).Discharge Pattern of Dudhnai Watershed, Brahmaputra Basin under the Influence of Climate Change. International Conference on Sustainable Technologies for River Erosion Alleviation and Management (STREAM 2022) during December 14-16, 2022 organized by Department of Civil Engineering, Indian Institute of Technology Guwahati & Brahmaputra Board held at Assam Water Centre, Guwahati.
94.	Swain, S., Mishra, S.K. and Pandey, A. (2023).A novel probabilistic approach of multi-scalar drought severity mapping using a bias-corrected blended precipitation product. The *Third International Workshop on BIODIVERSITY AND CLIMATE CHANGE - Sustainable Development Perspective (BDCC 2023)*, IIT Kharagpur, India, 16-19 February 2023.
95.	Swain, S., Nandi S., Mishra, S.K. and Pandey, A. (2022).Assessing the impacts of climatic and socio economic changes on drought vulnerability of a transboundary river basin in India: A multi-dimensional perspective.*The water security and Climate change conference* Bangkok, Thailand, 01-03 December 2022(Virtual Mode).
96.	Tejaswi, A., Sahoo, B., Kale, R.V. and Murty, P.L.N (2022). Integrated ADCIRC-SWAN-HEC-RAS 2D Modelling Framework for Cyclonic Coastal Flood Inundation Mapping. Proceedings of the 3rd IAHR Young Professional Congress organized by the International Association for Hydro-Environment Engineering and Research (*IAHR*) during 28 Nov – 1 Dec 2022 (Online mode).
97.	Thakur, A., Sharma,A., Sarkar,A. and Thakural, L.N. (2022). Assessment of the suitability of several precipitation datasets for the Upper Yamuna Basin upto Delhi, 27th International Conference On Hydraulics, Water Resources, Environmental and Coastal Engineering organised by Department of Civil Engineering, Punjab Engineering College, Chandigarh during 22nd-24th December, 2022.
98.	Thakur, D., Sharma, A., Sharma, M.K., Anand,L.V., Sharma, R.K. and Kumar, S. (2022).Factors affecting fluoride concentration in groundwater of semi-arid region, India, 9th International Ground Water Conference (IGWC-2022), organized by IIT Roorkee during 2-4 November,2022, at Roorkee (Uttarakhand), India.
99.	Thakural, L.N., Abhishikta, Samad, A., Alam,M., Ansari,I. and Lohani, A.K. (2022).Geospatial and AHP Techniques for Selection of Potential Zones for Water Harvesting in Dehradun, Uttarakhand. 9th International Groundwater Conference- 2022 organized by I.I.T. Roorkee, November 2-4, 2022.
100.	Thakural, L.N., Bamrara, M., Mishra,N., Samad,A., Alam, M., Lohani, A.K. and Thakur, A. (2022). Morphometric Characterization of Netravati River Basin using Geospatial Tools,

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101.	Thakural, L.N., Kumar,S., Ansari, I., Lohani,A.K., Patra,J.P. and Gurrapu, S. (2022).Evaluating long-term temperature trends for districts of Gujarat, India. International Conference ICCWE2022: Climate and weather-related extremes - New dimensions, Challenges, and Solutions organized by I.I.T. Roorkee, September 19-20, 2022.
102.	Thomas, T., Sharma, G., Nayak, P.C., Venkatesh, B. and Patel, L. (2022). Development of a Framework for Integrated Assessment of Drought Vulnerability in Chambal basin in Western Madhya Pradesh. Proceedings of the International Conference on Water and Environmental Management (WEM-2022): Sustainable Water Management in the context of Changing Environment, organised by Centre for Water Resources Development and Management, Kozhikode during 22-24 June 2022 at Kozhikode (Kerala), India.
103.	Tomar, A., Rajpal, A., Kazmi, A.A. andTyagi, V.K. (2022). Removal of Nutrients from Dairy Wastewater using Sequencing Batch Reactor. In: 7th India Water Week conclave, 1st -5th November 2022, Greater Noida, India Oct 29-31, 2022.
104.	Tyagi, V.K., Arora, P., Kapoor, A. and Kazmi,A.A. (2022).Biorefinery of Municipal Solid Waste in a Circular Bio-economy: Case study of 100 TPD Mechanical-Biological Treatment Plant in International Conference on Biotechnology for Sustainable Bioresources and Bioeconomy (BSBB-2022) organized by Indian Institute of Technology, Guwahati, India, December 7-11, 2022.
105.	Tyagi, V.K., Balasundaram, G., Gahlot, P. and Kazmi, A.A. (2022). Thermal hydrolysis of sewage sludge: Organics solubilization, methane yield, and emerging contaminants & pathogens removal": 13th International symposium on southeast asian water environment, 13th-15th December 2022, Bangkok, Thailand.
106.	Venkatesh, B., Abhilash, R., Thomas, T. and Nayak, P.C. (2022).Potential flood zone mapping for risk mitigation of Rakasakoppa dam, Belagavi, India, Three Day International Conference on “Dam Safety” organized by DRIP, CWC New Delhi at Jaipur from Oct7-8,2022.
107.	Venkatesh, B., Mishra,N., Panandiker,A.P. and Mesquita, M.D.S. (2022).Modelling Of Daily Rainfall of Goa State Using Hmm Model, International Virtual Conference on Developments and Applications of Geomatics, (DEVA-2022), Organized by Department of Civil Engineer, NIT Warangal, during August 29-31, 2022.
NATIONAL CONFERENCE/SEMINAR/WORKSHOP	
1.	Chakravorty, B. (2022).An Integrated Approach for Managing of Waterlogged and Drainage Congested areas in Lower Gandak Basin- A Modelling Approach.In the National Workshop on Agricultural Water Management in Changing Climate at organized byICAR RCER Patna on 27 March, 2023.
2.	Krishan, G. (2022).An insight from isotopic data to understand salinity mechanism in the aquifers of semi-arid regions of the north-west, India. In: INC-IAH National Seminar on “Recent approaches in groundwater development and management in arid/semi-arid region of India with a focus on Rajasthan” organized by INCIAH, RIET-Jaipur and Groundwater department, Rajasthan on December 24, 2022.
3.	Mandloi, S., Chakravorty, B. and Mani, P. (2022). Morpho-dynamic changes of Ganga River reach from Sultanganj to Bhagalpur using Remote Sensing Techniques.Proceedings of the National Seminar on Role of Agriculture and Statistics for Sustainable Natural Resources Management (SNRM) organized byDepartment of Farm Engineering, Banaras Hindu University during 11-12December, 2022 at Varanasi, U.P.
4.	Nayak, P.C., Thomas, T. and Venkatesh, B. (2022). Spatio-temporal analysis of rainfall pattern for Krishna basin, Two Day National Symposium on Advances in Weather and Climate prediction and Climate change Projection over South Asia: Applications in Water and Agriculture Sectors on 29th November to 2nd December 2022 organized by Indian Institute of Science, Education and Research (IISER) Bhopal.
5.	Nema, M.K. and Sekhar, M. (2022).Soil Moisture India Network (SMIN) : Exploring

	Research Possibilities and Expansion of the Network was presented during an online session of UK-India Smart Farm Club (SFC) on Nov 04, 2022.
6.	Pandey, R.P. (2022). Environmental Challenges and Water Resources Management for Resilient Ecosystem in Arid Regions invited Key paper presented in National Conference on Desert Ecosystems: Status, Emerging Challenges and Perspectives, November 15-16, 2022, Jaipur.
7.	Pandey, R.P. (2023). Challenges on sustainability of water resources for drinking water and irrigation. Key note paper presented in Water Summit: 2023 on "Water Security in India: Challenges & Prospects". Organized jointly by the Center for Advance Water Technology and Management and Gurugram University, ManavRachna, International Institute of Research and Studies, 24th February 2023, Faridabad-121004, Haryana
8.	Pandey, R.P. and Galkate, R.V. (2022). Impact of Climate Change on Occurrence of Regional Droughts. Invited lead paper presented in "31st National Conference on Innovative Resource Management Approaches for coastal and Inland Ecosystems to Sustain Productivity" and Climate Resilience, 13-15 Oct 2022, Navsari, Organized by Agricultural University, Navsari, Gujarat.
9.	Prasad, B., Tiwari, H.L., Galkate, R.V. and Khare, S. (2022). Rainfall Runoff Modeling for Wainganga River Sub-Basin Using HEC-HMS Model. IJEP 42(B): 1101-1107.
10.	Rao, Y.R.S. and Swain, S. (2023). Hydrological regime of the Godavari Delta under varying climatic conditions and Land use changes. In: Workshop proceedings on "Climate Change Adaptation & Mitigation" held on 27th January 2023 at Ambajipet, Andhara Pradesh.
11.	Rawat, S.S., Gurjar, S., Bisht, D.S., Kumar, S., Raina, G. and Khurana, D. (2022). हिमालयी जल स्रोतों के कुशल प्रबंधन एवं पुन रुद्धार के लिए वेब-जी.आई.एस.आधारित सूचना प्रणाली. भारतीय हिमालयी पर्यावरण को प्रभावित करने वाले कारक एवं प्रबंधन. जी.बी. पंत राष्ट्रीय हिमालयी पर्यावरण संस्थान, अल्मोड़ा, 28-29, July 2022.
12.	Rawat, S.S., Kumar, S. and Bisht, D.S. (2022).Springshed Management: Need for the Development of Scientific Approach and Protocols at Regional Scale. National Symposium Cum Workshop on Springhshed Management organized by NERIWALM, Tezpur, India, during 18-19 November 2022 at Tezpur (Assam), India.
13.	Thomas, T., Nayak, P.C. and Venkatesh, B. (2022).Long-term Changes in Climatic Variables – a case study for Chambal basin in Central India., National Symposium TROPMET 2022: Advances in Weather and Climate Prediction and Climate Change Projection over South Asia: Applications in Water and Agriculture Sectors organised by Indian Institute of Science Engineering and Research, Bhopal during 29 November – 2 December, 2022 at Bhopal (MP), India.
14.	Tomar, A., Rajpal,A., Kazmi,A.A., Goel, A.K. and Tyagi, V.K. (2023).Advanced anaerobic bio-digester: A DRDO based bio-digester for human fecal treatment. In: Institute Research Day, March 14, 2023 at Indian Institute of Technology Roorkee.
15.	Tomar, A., Rajpal,A., Kazmi,A.A., Goel, A.K. and Tyagi, V.K. (2023).Sustainable Solution for Sanitation: A DRDO based bio-digester for human fecal treatment. In: Uttarakhand UdyogMahotsava, March 18-20, 2023.
16.	Venkatesh, B., Bharat, A.L., Nayak, P.C. and Thomas, T. (2022). Evaluation of various Characteristics of Precipitation Concentration Index in part of Western Ghats, Two Day National Symposium on Advances in Weather and Climate prediction and Climate change Projection over South Asia: Applications in Water and Agriculture Sectors on 29th November to 2nd December 2022 organized by Indian Institute of Science, Education and Research (IISER) Bhopal.

LIST OF PAPERS PUBLISHED DURIG 2023-24 (upto August 2024)

	INTERNATIONAL JOURNAL
1.	S. Singh, N. Pawar, S. S. Kumar, R. Singh, G. Anand, A. Kumar, S. K. Malyan (2023). Aromatic oils from medicinal plants, and their role in nanoparticles synthesis, characterization, and applications (In. Secondary metabolites from medicinal plants: Nanoparticles synthesis and their applications. Eds. R. K. Bachheti, A. Bachheti), CRC Press, Taylor & Francis Group, Boca Raton, FL (ISBN: 978-1-032-07515-0).
2.	Omkar Singh, Rajesh Singh, Kalzang Chhoden, N. R. Allaka, Digambar Singh, V. C. Goyal (2023), Rejuvenation of Village Ponds and Performance Evaluation of Natural Treatment System: Few Case Studies, Water Management & Governance, Published by ABS Books; ISBN : 978-93-94424-71-5.
3.	Sharma, M. K., Thayyen, Renoj J., Jain, C. K., Arora, Manohar and Shyamlal (2022) "Seasonal Variations of Major Ion Chemistry and Solute Fluxes of Meltwater of River Bhagirathi, a Himalayan Tributary, India" in the Edited Book titled "Groundwater and Water Quality" Hydraulics, Water Resources and Coastal Engineering (Eds. R. Jha, V. P. Singh, V. Singh, L. B. Roy, Roshni Thendiyath) Water Science and Technology Library, Vol. 119 (ISBN 978-3-031-09550-4), Springer Nature Switzerland AG, pp. 387-398.
4.	Gahlot, P., Alley, K. D., Arora, S., Das, S., Nag, A., & Tyagi, V. K. (2023). Wastewatersurveillance could serve as a pandemic early warning system for COVID-19 and beyond. WIREs Water, e1650.
5.	Henok, M. A.; Mishra, S. K.; and Goel, M. K. (2023). "Assessing the impact of climate change on the hydrology of Gidabo river sub-basin, Ethiopian Rift Valley Lakes Basin", Journal of Sustainable Water Resources Management, 9:65; https://doi.org/10.1007/s40899-023-00858-7
6.	Joshi S. K., S. Kumar, R. Sinha, S. P. Rai, S. Khobragade, M. S. Rao (2023) Identifying moisture transport pathways for north-west India. Geological Journal https://doi.org/10.1002/gj.4759 (IF: 2.2)
7.	Krishan G, Mohit Kumar, M S Rao, R Garg, B K Yadav, ML Kansal, Surjeet Singh, A Bradley, M Muste, LM Sharma (2023) Integrated approach for the investigation of groundwater quality through hydrochemistry and water quality index (WQI) Urban Climate, 47, 101383 (IF: 6.97)
8.	Swain, S., Mishra, S. K., Pandey, A., Srivastava, P. K., & Nandi, S. (2023). Characterization and assessment of hydrological droughts using GloFAS streamflow data for the Narmada River Basin, India. Environmental Science and Pollution Research, 1-14. https://doi.org/10.1007/s11356-023-27036-8
9.	Godvin Sharmila V, Surya Prakash Shanmugavel, Vinay Kumar Tyagi, Rajesh Banu J (2023) Microplastics as emergent contaminants in Landfill leachate: Source, potential impact and remediation technologies. Journal of Environmental Management, 343, 118240.
10.	Sandeep Singh, Sandeep K Malyan, Chinmay Maithani, Sujata Kashyap, Vinay Kumar Tyagi, Rajesh Singh, Sarthak Malhotra, Manish Sharma, Amit Kumar, Bijay K. Pandey, R. P. Pandey (2023) Microplastics in landfill leachate: Occurrence, health concerns and removal strategies. Journal of Environmental Management, 342, 118220.
11.	Kalzang Chhoden, Chhavi K. Manchanda (2023), Ground Water and Pond Water Quality Assessment of District Ropar, Punjab, Water Science and Technology, Published by ABS Books; ISBN : 978-93-94424-62-3.
12.	Krishan, Gopal, Ghosh, Srijita, Virk, H.S. 2023. Arsenic pollution and associated human health hazards in Rupnagar district, Punjab, India. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-023-27247-z
13.	Patil, M., Saha, A., Pingale, S.M., Rathore, D.S., & Goval, V.C. (2023). Identification of potential zones on the estimation of direct runoff and soil erosion for an un gauged watershed based on remote sensing and GIS techniques. International Journal of

	Engineering and Geosciences, 8(3), 224-238. https://doi.org/10.26833/ijeg.1115608
14.	Anjali Bhagwat, Chandra Shekhar Prasad Ojha, Distributed mathematical model for simulating temperature profile in landfill, Waste Management, Volume 167,2023,Pages 64-73,ISSN 0956-053X,https://doi.org/10.1016/j.wasman.2023.05.024
15.	Prakasam, C., Saravanan, R., Machiwal, D. and Sharma, M. K. (2023) Rainfall-runoff modelling using HEC-HMS model in an ungauged Himalayan catchment of Himachal Pradesh, India, Arabian Journal of Geosciences, 16:417, 1-17.
16.	S. Singh, S. K. Malyan, C. Maithani, S. Kashyap, V. K. Tyagi, R. Singh, S. Malhotra, M. Sharma, A. Kumar, B. K. Panday, R. P. Pandey (2023). Microplastics in landfill leachate: Occurrence, health concerns, and removal strategies. Journal of Environmental Management, 342, 118220 (I.F.: 8.91).
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7वीं राष्ट्रीय जल संगोष्ठी 17-18 **अगस्त**, 2023" :**जलवायु परिवर्तन एवं जल प्रबंधन** ."**राष्ट्रीय जल विज्ञानं संस्थान रूड़की**

राष्ट्रीय जल विज्ञान संस्थान के प्रतिभागियों द्वारा प्रस्तुत प्रपत्रों की सूची

प्र.सं.	विषय	लेखक
1	जून 2013 में केदारनाथ घाटी मध्य हिमालय, भारत में आई बाढ़ का समस्थानिक (Isotopic) अध्ययन	राजीव सरन अहलूवालिया[1], एस.पी. राय[2], संजय कुमार जैन[3], एवं द्रोण खुराना[4] [1]दून विश्वविद्यालय, उत्तराखंड [2]बनारस हिंदू विश्वविद्यालय, वाराणसी, उत्तर प्रदेश [3]राष्ट्रीय जलविज्ञान संस्थान, रुड़की [4]राष्ट्रीय जलविज्ञान संस्थान, क्षेत्रीय केंद्र जम्मू
2	यमुना–हिंडन इंटर–बेसिन के कृषि क्षेत्र में भारी धातु का संदूषण	दिव्या ठाकुर, अनुपमा शर्मा, मयंक रतूड़ी, धीरज कुमार राष्ट्रीय जलविज्ञान संस्थान रुड़की
3	ऊपरी यमुना घाटी में भूमि और जल संसाधनों के सतत प्रबंधन के लिए बहु भूमि उपयोग और वाष्पोत्सर्जन के आंकलन का एकीकरण	पी.के. मिश्रा, अनुपमा शर्मा, धीरज मोहन गुरूरानी एवं प्रखर शर्मा राष्ट्रीय जलविज्ञान संस्थान रुड़की
4	ऊपरी यमुना बेसिन में विभिन्न परियोजनाओं के विकास का हथिनीकुंड बैराज में जल उपलब्धता का प्रभाव विश्लेषण	एम.के. गोयल, पी.के. मिश्रा, पी.के. सिंह एवं पी.के. अग्रवाल राष्ट्रीय जलविज्ञान संस्थान रुड़की
5	उत्तराखंड में रिस्पना नदी के पुनर्जीवीकरण हेतु निष्पाद्य योजना	आर.पी. पाण्डेय, प्रदीप कुमार, जयवीर त्यागी, राजेश सिंह एवं अरूण कुमार राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
6	मध्य–भारत की वैन गंगा नदी बेसिन में मौसम विज्ञानीय सूखे से जलविज्ञानीय सूखे के रूपांतरण का विश्लेषण	मनीष कुमार नेमा एवं संजीव एस. परिहार राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
7	गुवाहाटी शहर में ब्रह्मपुत्र रिवरफ्रंट का जल गतिकीय प्रवाह निदर्शन आधारित अभिकल्पन	पंकज मणि, राकेश कुमार, एवं जगदीश प्रसाद पात्रा राष्ट्रीय जलविज्ञान संस्थान, रुड़की 247 667, उत्तराखंड
8	उत्तराखंड के जिला हरिद्वार में स्थित इब्राहिमपुर मसाही ग्राम में जल की मांग एवं वर्षा जल एकत्रीकरण की संभाव्यता का आंकलन	पुष्पेन्द्र कुमार अग्रवाल, ओमकार सिंह, ए.आर. सेंथिल कुमार, राजेश अग्रवाल एवं नागेश्वर राव अल्लका राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
9	ओडिशा में भेदन नदी के अनुप्रवाह क्षेत्रों में बाढ़ प्रबंधन	जगदीश प्रसाद पात्रा, राकेश कुमार, पंकज मणि, संजय कुमार एवं तिलक राज सपरा राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667
10	दक्षिण पश्चिम पंजाब के लवणता प्रभावित	गोपाल कृष्ण[1], प्रकृति गुप्ता[2], एम. एस. रावं[1], प्रिंस वत्स[3], सुरजीत

	क्षेत्रों का जलभृत विवरण और मानचित्रण	सिंह[1], राजेश वशिष्ठ[4] [1]राष्ट्रीय जलविज्ञान संस्थान, रुड़की [2]टी.ई.आई. स्कूल ऑफ एडवांस्ड स्टडीज, नई दिल्ली [3]आई.आई.टी. रोपड़, [4]पंजाब जल संसाधन विकास प्राधिकरण, चंडीगढ़
11	भूजल में आर्सेनिक प्रदूषण और उपलब्ध एक्स–सीटू–उपचारात्मक रणनीतियाँ	शशि रंजन, सुरजीत सिंह, कुमार सुमंत, दीपेन्द्र कुमार सिंह राष्ट्रीय जलविज्ञान संस्थान, रुड़की
12	मध्य गंगा बेसिन के उत्तर प्रदेश क्षेत्र में भारी धातुओं से भूजल संदूषण और स्वास्थ्य जोखिम का आंकलन	एम. सोमेश्वर राव, मोहित जोशी एवं सुधीर कुमार राष्ट्रीय जलविज्ञान संस्थान रुड़की
13	बंगाल की खाड़ी में अन्तः समुद्री भूजल निर्वहन तथा समुद्री जल अंतर्वेधन का अध्ययन	एम. सोमेश्वर राव[1], मोहित जोशी[1], सुधीर कुमार[1], सुब्रतो हलधर[2] एवं वैशाली सिंह[1,3] [1]राष्ट्रीय जलविज्ञान संस्थान, रूड़की, [2]स्विड (SWID), पश्चिमी बगांल, सरकार, [3]केन्द्रीय यूनिवर्सिटी, बठिंडा
14	भूजल अनुसंधान के क्षेत्र में सुदूर संवेदन विधियों का उपयोग	अंजु चौधरी[1] एवं पल्लवी चौधरी[2] [1]राष्ट्रीय जवलविज्ञान संस्थान, रूड़की, [2]राजकीय पॉलीटेक्निक, श्रीनगर, गढ़वाल (उत्तराखंड)
15	भारतवर्ष के मथुरा–आगरा क्षेत्र के गहरे मृदा प्रोफाइल में प्रमुख घटक विश्लेषण (PCA) के उपयोग द्वारा भारी धातु संदूषण का आंकलन	संजय मित्तल, एस.एल. श्रीवास्तव, गोपाल कृष्ण राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
16	उत्तर प्रदेश के मुजफ्फरनगर और मेरठ जनपदों में चिन्हित तालाबों के आस–पास मृदा के भौतिक रासायनिक और जलविज्ञानीय गुणों का आंकलन	कलजंग छोड़न, राजेश सिंह, ओंकार सिंह एवं वी.सी. गोयल राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667,
17	भौगोलिक सूचना तंत्र अनुप्रयोग का उपयोग कर बेमेतरा जिले में भूजल प्रदूषण मूल्यांकन और खराब गुणवत्ता वाले क्षेत्रों की पहचान	मोहित कुमार[1], मुकेश कुमार शर्मा[1] एवं देवेंद्र सिंह मलिक[2], [1]राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड [2]गुरूकुल कांगड़ी (डीम्ड यूनिवर्सिटी), हरिद्वार 249 404 उत्तराखंड
18	गोदावरी नदी बेसिन में वार्षिक और मौसमी बाढ़ पर एल नीनो दक्षिणी दोलन का प्रभाव	सुनील गुर्रपु, संजय कुमार राष्ट्रीय जलविज्ञान संस्थान, रूड़की
19	जलवायु परिवर्तन पर भारतीय अनुसंधान : एक विश्लेषण	डॉ. सुसांत कुमार सेनापति[1], एवं मौ. फुरकान उल्लाह[2] [1]केन्द्रीय भवन अनुसंधान संस्थान रूड़की, [2]राष्ट्रीय जलविज्ञान संस्थान रूड़की,
20	मध्य भारत में विभिन्न अनुमानों के तहत जल संतुलन घटक पर जलवायु परिवर्तन का प्रभाव	आराधना ठाकुर[1], [1]प्रभाष कुमार मिश्रा एवं अनुपम कुमार नेमा[2], [1]राष्ट्रीय जलविज्ञान संस्थान रूड़की [2]बनारस हिन्दू विश्वविद्यालय, वाराणसी, उत्तर प्रदेश
21	जल संसाधनों में जलवायु परिवर्तन के लिए अनुकूलन रणनीतियाँ : विशिष्ट रूप से भारतीय परिप्रेक्ष्य में	मनोहर अरोड़ा राष्ट्रीय जलविज्ञान संस्थान, रुड़की
22	जल संरक्षण और जलवायु परिवर्तन की चुनौतियों के समाधान में अंतर्राष्ट्रीय संगठनों विशेष रूप से यूनेस्को की भूमिका	अमरेन्द्र भूषण, ओंकार सिंह, ज्योति, पी. पाटिल, एवं सुधीर कुमार राष्ट्रीय जलविज्ञान संस्थान, रुड़की 247 667, उत्तराखंड
23	वैश्विक जलवायु परिवर्तन का मानसूनी वर्षा पर प्रभाव	अश्विनी रानडे राष्ट्रीय जलविज्ञान संस्थान, रुड़की–247 667
24	जल प्रदूषण अनुसंधान में आर्टिफिशियल इंटेलिजेंस (ए.आई.) का उपयोग	प्रिंस वत्स[1] एवं नरेश कुमार[2] भारतीय प्रौद्योगिकी संस्थान रोपड़, रूपनगर[1] राष्ट्रीय जलविज्ञान संस्थान रूड़की[2]
25	घरेलू अपशिष्ट जल से क्षैतिज उप–सतही	श्वेता यादव, ओंकार सिंह, राजेश सिंह, ज्योति सिंह, एवं रीतिका

	प्रवाह निर्मित आर्द्रभूमि द्वारा प्रदूषकों का निवारण	नेगी राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
26	औद्योगिक अपशिष्ट जल के उपचार और पुनः प्रयोज्य के लिए एक उन्नत एनारोबिक–एरोबिक प्रणाली	विनय कुमार त्यागी राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667
27	गंगोत्री हिमनद के हिमगलन से प्राप्त जल के रासायनिक अभिलक्षणों में अवसाद का योगदान	मुकेश कुमार शर्मा, बबीता शर्मा एवं बीना प्रसाद राष्ट्रीय जलविज्ञान संस्थान, रुड़की 247 667, उत्तराखंड
28	जल संसाधन में उदीयमान प्रदूषक	सुजाता कश्यप[1], राजेश सिंह[2] [1]एक्सा पैरेंट्रल लिमिटेड, रुड़की–247 667 [2]राष्ट्रीय जलविज्ञान संस्थान, रुड़की–247 667
29	जलविज्ञान और जल संसाधन विकास तथा प्रबंधन में प्रशिक्षण, अनुसंधान और अनुप्रयोग का महत्व	तिलक राज सपरा, जे.पी. पात्रा राष्ट्रीय जलविज्ञान संस्थान रुड़की
30	मृदा से जल का वाष्पीकरण एवं पौधों से होने वाले वाष्पन के मापन में समस्थानिक तकनीक	गोपाल कृष्ण[1], एम.एस. राव[1], पंकज ठाकुर[1], बलजिंदर सिंह[1], स्वेता, वी.एस[1], प्रवेश सिंह[2], साहिर आजम शाद[2], आर. ओझा[2], आर. श्रीवास्तव[2], शिवम त्रिपाठी[2] एवं एस. गुहा[2] [1]राष्ट्रीय जलविज्ञान संस्थान रूड़की [2]भारतीय प्रौद्योगिकी संस्थान, कानपुर
31	जलवायु परिवर्तन परिस्थितियों में स्मार्ट एवं सतत जल प्रबंधन में इंटरनेट ऑफ थिंग्स (loT) तकनीकों की भूमिका	संतोष मुरलीधर पिंगले, सोबन सिंह रावत एवं सुहास खोब्रागडे राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
32	**2x660MW** कोयला आधारित सुपर थर्मल पॉवर प्रोजेक्ट, खुर्जा के लिए जलालेखीय क्षेत्र निकासी अध्ययन	पंकज मणि, जे.पी. पात्रा, राकेश कुमार, तिलक राज सपरा राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
33	हरियाणा राज्य के मेवात क्षेत्र के लिए जल मूल्यांकन एवं योजना (WEAP) मॉडल द्वारा जल की मांग–आपूर्ति के अंतर का आंकलन	ए.आर. सेंथिल कुमार, नागेश्वर राव अलक्का, ओमकार सिंह, राजेश अग्रवाल राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, उत्तराखंड
34	जल प्रबन्धन में निर्णय समर्थक तंत्र की भूमिका	अनिल कुमार लोहनी राष्ट्रीय जलविज्ञान संस्थान, रुड़की–247 667
35	उत्तराखंड के पर्वतीय क्षेत्रों में प्राकृतिक झरनों की वर्तमान स्थिति, भूजल जलविज्ञान एवं कायाकल्प योजना पर अध्ययन	पंकज कुमार ठाकुर[1], विनोद कुमार बाल्यान[2], गोपाल कृष्ण[3] [1,3]राष्ट्रीय जलविज्ञान संस्थान, रूड़की, [2]गोविंद बल्लभ पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय, पंतनगर–263 145
36	भारतीय हिमालयी क्षेत्र में प्राकृतिक जल स्रोतों की स्थिति	दिव्या ठाकुर, सोबन सिंह रावत, दीपक सिंह बिष्ट, सुधीर कुमार एवं आयुष कुकरेती राष्ट्रीय जलविज्ञान संस्थान, रूड़की
37	हिमालयी कैचमेंट में उपसतही मृदा–नमी के लिए एक अनुभवजन्य मॉडल का विकास, आंकलन और परिवर्तनीयता मूल्यांकन	संगीता वर्मा[1] एवं मनीष कुमार नेमा[2] [1]भारतीय प्रौद्योगिकी संस्थान, रुड़की–247 667 [2]राष्ट्रीय जलविज्ञान संस्थान, रुड़की 247 667
38	हसदेव नदी जलग्रहण के लिए सतही अपवाह पर भूमि–उपयोग एवं भूमि–आवरण परिवर्तन के प्रभावों का आंकलन	अनुराधा साहू[1], मनीष कुमार नेमा[2], एवं वीरेंद्र कुमार चंदोला[1] [1]कृषि विज्ञान संस्थान, बनारस हिन्दू विश्वविद्यालय, वाराणसी, 221 005 [2]राष्ट्रीय जलविज्ञान संस्थान, रुड़की 247 667
39	बहुभिन्नतरूपी सांख्यिकी (Multivariate Statistics) का उपयोग करते हुए अलकनंदा नदी, उत्तराखंड के सतही जल का जल रासायनिक मूल्यांकन	कुनारिका भनोट[1], मुकेश कुमार शर्मा[2] एवं रजनीश दत्त कौशिक[2] [1]गुरूकुल कांगड़ी (डीम्ड यूनिवर्सिटी), हरिद्वार 249 404 उत्तराखंड [2]राष्ट्रीय जलविज्ञान संस्थान, रुड़की 247 667, उत्तराखंड
40	पश्चिमी हिमालय की दो भिन्न–भिन्न घाटियों में स्थित हिमनदों और उनसे प्राप्त	विशाल सिंह, मनोहर अरोड़ा एवं संजय कुमार जैन राष्ट्रीय जलविज्ञान संस्थान, रुड़की–247 667

	हिमनदगलन अपवाह परिवर्तन का तुलनात्मक अध्ययन	
41	रासायनिक उर्वरकों के अत्यधिक उपयोग का जल संसाधनों पर प्रभाव	प्रिंस वत्स[1] एवं नरेश कुमार[2] [1]भारतीय प्रौद्योगिकी संस्थान रोपड़, रूपनगर [2]राष्ट्रीय जलविज्ञान संस्थान रूड़की
42	कृषि में सिंचाई के लिए जल संसाधनों के इष्टतम उपयोग एवं जल प्रबंधन हेतु वेब आधारित निर्णय समर्थन प्रणाली	सुमित कुमार[1], वर्णिका[2], राहुल कुमार जायसवाल[2], [2]रवि गलकटे, [1]अनिल कुमार लोहनी, [1]राष्ट्रीय जलविज्ञान संस्थान रुड़की, [2]राष्ट्रीय जलविज्ञान संस्थान क्षेत्रीय केंद्र भोपाल
43	जल अभाव क्षेत्रों में टपक सिंचाई द्वारा सटीक कृषि	सतेन्द्र कुमार[1], अनुपमा शर्मा[1], कनक जोधा[1], प्रदीप कुमार[2], एवं रतन पंवार[3] [1]राष्ट्रीय जलविज्ञान संस्थान रुड़की [2]एम.बी.एम. अभियान्त्रिकी महाविद्यालय, जोधपुर [3]भाकृअनुप–केंद्रीय शुष्क क्षेत्र अनुसंधान संस्थान, जोधपुर
44	सुदूर संवेदन एवं भौगोलिक सूचना तंत्र तकनीक का उपयोग करके स्थानिक फसल मानचित्रण और सटीकता मूल्यांकन	सौरभ नेमा[1], मनीष कुमार नेमा[2], एवं मनोज अवस्थी[3] [1]राष्ट्रीय जलविज्ञान संस्थान, जोधपुर 342 003 [2]राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667, [3]जवाहरलाल नेहरू कृषि विश्वविद्यालय, जबलपुर–482 004
45	नहर कमांड क्षेत्र के लिए भूमि एवं जल उत्पादकता का अनुमान लगाने में उपग्रह आधारित ओपन एक्सेस आंकड़ों की उपयोगिता	पी.के. मिश्रा, पी.के. सिंह, पी.के. अग्रवाल, नरेश कुमार राष्ट्रीय जलविज्ञान संस्थान, रुड़की–247 667
46	सतही जल और भूजल प्रबंधन में वर्षा जल संचयन की भूमिकाः विधियों, प्रौद्योगिकियों और लाभों पर एक अवलोकन	संतोष मुरलीधर पिंगले, एस.डी. खोब्रागडे एवं राजीव गुप्ता राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667,
47	पश्चिमी राजस्थान के थार रेगिस्तान में जल जीवन मिशन की स्थिरता हेतु जल संचयन की महत्वपूर्ण तकनीकें	वरूण गोयल एवं डॉ. वी.सी. गोयल राष्ट्रीय जलविज्ञान संस्थान, रूड़की 247 667

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LIST OF WORKSHOPS/ TRAINING COURSES/ SYMPOSIA ORGANISED DURING APRIL 2022 – MARCH 2023 & APRIL 2023 – AUGUST 2023

TRAINING COURSES/WORKSHOPS ORGANISED DURING 2022-23 & 2023-24 (upto August)

SN	ACTIVITES	PERIOD	VENUE
INTERNATIONAL ACTIVITIES			
1.	9th International Groundwater Conference (IGWC-2022) Effective Management of (Sub)-Surface Water Resources in Arid and Semi-arid Regions (Joint Organizing Secretary- Gopal Krishan)	November 02-04, 2022	Dep. of Hydrology, IIT Roorkee
NATIONAL ACTIVITIES			
CONFERENCES/SEMINARS/SYMPOSIA			
1.	The Soil Moisture India Network (SMIN) Steering Committee Meeting along with the Soil Moisture India Network (SMIN) Stakeholders' Workshop	June 07, 2022	NPMU-NHP, New Delhi
2.	Workshop on Application of Decision Support System (Planning &Management) for Upper Krishna Basin	August26, 2022	YASHADA, Pune
3.	Organized Inception Workshop under NHP special studies entitled "Comprehensive Assessment of Water Availability, Use and issues for Goa State"	September 23, 2022	Water Resources Department, Goa
4.	Special Session for Young Professionals on "Water Security for Sustainable Development with Equity" in 7th India Water Week-2022 (IWW-2022)	November 03, 2022	India Expo Center, Greater Noida
5.	National Symposium cum Workshop on "Springshed Management" jointly organized by North Eastern Regional Institute of Water and Land Management (NERIWALM), National Institute of Hydrology and Central Ground Water Board	November 18-19, 2022	NERIWALM, Tezpur
6.	Modellers Meet under NHP	December 19-20, 2022	New Delhi
7.	Organized the Training Workshop on "Role of Hydrology inUrban Flood Management"	February 06-08, 2023	DRC, NIH, Kakinada
8.	Involved in the organization of 02-day Technical Workshop entitled"WEB.BM model applications for optimization analysis of reservoir systems operation" with Dr. Nesa, Ilich, International Consultant, TAMC under NHP as key resource person	March 13-14, 2023	NIH, Roorkee
TRAINING COURSES/WORKSHOPS			
1.	Training Workshop on "Hydrodynamic Modelling using HEC-RAS"	April 07-08, 2022	Gandhi Nagar
2.	12-day Training Programme on "Water Resources Planning and Management" sponsored by META, Nashik	April 15-25, 2022	NIH, Roorkee
3.	Training Workshop on "Flood Management and Erosion Control" in collaboration with NEHARI, Brahmaputra Board	April 18-22, 2022	NEHARI, Brahmaputra Board
4.	Training on "Remote Sensing and GIS" in the Induction Course for Newly Appointed AE's of WRD (Irrigation), Govt. of Bihar in four batches(50 participants) organized by CFMS, Patna	May02, May 12, May 23 and May 30, 2022	Jointly with WALMI, Patna
5.	05-day Training Workshop on "Flood Management and	May	NEHARI,

	Erosion Control" organised by NIH and NEHARI	09-13, 2022	Brahmaputra Board
6.	Training on "Approaches for Management of Groundwater Quantity and Quality with special focus on MAR" jointlyorganized by NIH and IIT, Roorkee	June06-10, 2022	Virtual mode
7.	Training on "Remote Sensing and GIS" in the Induction Course for Newly Appointed AE's of Project and Development (P&D) Department, Govt. of Bihar in four batches(50 participants) organized by CFMS, Patna	June 06, June 30, July13 and July26, 2022	Jointly with WALMI, Patna
8.	05-day Training on "National Hydrology Model"sponsored by National Hydrology Project (NHP)	August 01-05, 2022	NIH, Roorkee
9.	Training on "Remote Sensing and GIS" in the Induction Course for Newly Appointed AE's of Building Construction Department, Govt. of Bihar in two batches (Virtual50 participants) organized by CFMS, Patna	August 01 and August 22, 2022	Jointly with WALMI, Patna
10.	05-day online training on "Hydrological Modeling using Soil and Water Assessment Tool (SWAT): Theory and Hands-on"sponsored by National Hydrology Project (NHP)	August 22-26, 2022	NIH, Roorkee
11.	01-day Training Workshop on "Tools and Techniques for Springshed Management" organized by NIH-WHRC in association with Government Degree College, Udhampur Jammu	September 03, 2022	Government Degree College, Udhampur
12.	Scientific Data Collection and Techniques for Springshed Management and Rejuvenation	September 06-09, 2022	NEHARI, Guwahati
13.	Training Workshop on "Flood management and Erosion Control" organised in association with NEHARI, Brahmaputra Board	September 09-23, 2022	NEHARI, Brahmaputra Board
14.	Brief presentation on "TUFLOW Hydraulic modelling software"	September 12, 2022	NIH, Roorkee (Virtual mode)
15.	Training Course on"River Hydraulics with 1D and 2D HEC-RAS" organised in association with US Army Corps of Engineer, USA	September 26-29, 2022	NIH, Roorkee
16.	Training on "Remote Sensing and GIS" in the Orientation Course for Chief Engineers of all Works Department of Govt. of Bihar (25 participants)organized by CFMS, Patna	October 31-November 04, 2022	Jointly with WALMI, Patna
17.	Training on "Remote Sensing and GIS" in the Induction Course for Newly Appointed AE's of WRD, Govt. of Bihar (50 participants) organized by CFMS, Patna	November 03-16, 2022	Jointly with WALMI, Patna
18.	05-day Online Training Programme on "Hydrologic and Hydrodynamic Flow Analysis Using HEC-HMS and HEC-RAS"	November 07-11, 2022	NIH, Roorkee
19.	Training Workshop on "Flood management and Erosion Control" organised in association with NEHARI, Brahmaputra Board	November 14-18, 2022	NEHARI, Brahmaputra Board
20.	Training cum workshop on "Advanced Tools and Techniques for Managed Aquifer Recharge (ATT-MAR)" jointlyorganized by NIH and IIT, Roorkee	November 21-25, 2022	IIT, Roorkee
21.	05-Day Training Course on "Integrated Water Resources Modelling under a Changing Climate in the Indian Himalayas"	November 21-25, 2022	NIH, Roorkee
22.	First Training of Trainers on "Usage and Applications of DSS(PM)"	November 21-December	NIH, Roorkee

		02, 2022	
23.	05-day Training Course on “Application of Water Accounting Plus (WA+) Tool for Water Resources Management”	November 28-December 02, 2022	Kohima, Nagaland
24.	Hydrological modelling using SWAT	December 05-09, 2022	NERC, NIH, Guwahati
25.	One-week Training Course on “Climate Change and Hydrological Impact Assessment”	December12-17, 2022	NIH, Roorkee
26.	Training Course on “Springshed Management”	December 13-15, 2022	DoLR, Kohima, Nagaland
27.	Training Course entitled “Hands-on Advanced Instrumentations in Water Quality Analysis” under NHP	January 16-20, 2023	NIH, Roorkee
28.	SERB Sponsored High-End Workshop [Karyashala] on the topic “Challenges in Water-Related Disasters Risk Reduction: Vulnerability, Adaptation and Resilience Techniques”	January 16-21, 2023	NIH, Roorkee
29.	Training Course entitled “Environmental Data Processing” under NHP	January 30-February03, 2023	NIH, Roorkee
30.	05-day Training Workshop on "Flood Management and Erosion Control" organised in association with NEHARI, Brahmaputra Board	February 06-10, 2023	NEHARI, Brahmaputra Board
31.	Training Course on “Water Quality Monitoring and Management” under NHP	February 13-17, 2023	NIH, Roorkee
32.	Training Course on “Hydro-meteorological Data Analysis: Basics and Advanced Techniques”	February 27-March 03, 2023	NIH, Roorkee
33.	05-day Training Programme on “Life cycle Approach for Rejuvenation of Ponds and Lakes Using Nature-based solutions”	March 13-17, 2023	DRC,NIH, Kakinada
34.	05-day Training Programme on “Life cycle Approach for Rejuvenation of Ponds and Lakes Using Nature-based solutions”	March 13-17, 2023	HRRC, NIH, Belagavi
35.	05-day Training Programme on “Life cycle Approach for Rejuvenation of Ponds and Lakes Using Nature-based solutions” organized by Central India Hydrology Regional Centre, Bhopal	March 13-17, 2023	State Water Data Centre, WRD, Bhopal
36.	01-day Training Course on “Analyzing Hydro-Meteorological Data Using R Programming Language”	March 17, 2023	WHRC, NIH, Jammu
37.	05-day Training Programme on “Flood Prone Area Mapping and Modeling” for I&WRD, Mizoram	March 20-24, 2023	NIH, Roorkee
38.	Training Course on “Water and Wastewater Treatment”	March 20-24, 2023	NIH, Roorkee
BRAINSTORMING SESSIONS			
1.	An “Awareness Session on IPR & Patent”	April 26, 2022	NIH, Roorkee
2.	Brainstorming Session on“Water Security in a Changing Environment- Focus on Indian Himalayan Region (IHR)” during 15th &16thUttarakhand State Science and Technology Congress(USSTC)under the aegis of INC-IHP	June 22, 2022	Graphic Era (Deemed to be) University, Dehradun
3.	Swachh Manthan on a theme “Accelerating Change to Solve Water and Sanitation Crisis” on the occasion of “World	March 22, 2023	CFMS, Patna

	Water Day" for Bihar Govt. officials		
OTHER ACTIVITIES			
1.	Shri T. Vijay, Scientist- 'B' delivered a lecture to the M. Tech students, Dept. of Health Science and Research, JNTU, Kakinada on Water Quality Aspects and provided hands-on training to the students on various methods of chemical analysis of water	April, 2022	DRC,NIH, Kakinada
2.	Dr. V.S. Jeyakanthan, Scientist- 'F' attended the summer school programmesponsored by ISRO and organized by IIT-Roorkee on the topic **"Emerging Space Technology Applications For Compound Extremes 2022** (STAC-X 2022)"	May 09-20, 2022	IIT, Roorkee
3.	Dr.Gopal Krishan as Technical Officer)TO(along with Miss. KimjamlhingSitlhouChongloi, Director, Tourism, Govt. of India as Central Nodal Officer)CNO(visited the Champawat district of Uttarakhandand reviewed "Water conservation works under Jal Shakti Abhiyan-Catch The Rain campaign-2022" and submitted the report to the Ministry of Jal Shakti, Dept. of Water Resources, RD & GR, Govt. of India	June 14-17, 2022	Champawat, Uttarakhand
4.	Er. R. Venkata Ramana visited the Wayanad District, Kerala under Jal Shakti Abhiyan CTR-2022	July 11-13, 2022	Wayanad, Kerala
5.	Dr. V.S. Jeyakanthan, Scientist- 'F' attended a 02-day Online Training Programme on the topic "Physical &Mathematical Modeling of Reservoir and Appurtenant Structures"	August 02–03, 2022	CWPRS, Pune
6.	Rajbhasha/Hindi Week	September 14-21, 2022	CFMS, Patna
7.	Dr. V.S. Jeyakanthan, Scientist- 'F' attended a 02-day Online Training Course on "Advanced Techniques Bathymetry Survey for Water Reservoirs and in Coastal Projects"	September 20-21, 2022	CWPRS, Pune
8.	Dr. Y.R.S. Rao, Scientist- 'G' gave a keynote lecture on "Groundwater quality assessment and river bank filtration- a source of safe drinking water" in the "Tier-III Training Programme on groundwater development and management in Kakinada District with special emphasis on aquifer mapping and management of Godavari delta, A.P."	October 27, 2022	District Collectorate, Kakinada
9.	Dr. S.M. Pingaleas Technical Officer)TO(along with Sh. Ateesh Singh, Joint Secretary, Ministry of Micro, Small and Medium Enterprises)MSME(, Govt. of India as Central Nodal Officer)CNO(visited the Tehri-Garhwal district of Uttarakhandand reviewed "Water conservation works in the Tehri-Garhwal district of Uttarakhand under Jal Shakti Abhiyan-Catch The Rain campaign-2022" and submitted the report to the Ministry of Jal Shakti, Dept. of Water Resources, RD & GR, Govt. of India	October 31-November 02, 2022	Tehri-Garhwal, Uttarakhand
10.	Dr. V.S. Jeyakanthan, Scientist- 'F' attended a 02-dayTraining Workshop on the topic "Hydrologic Unit Model for India-HUMID" conducted by IIT, Madras in collaboration with NRSC, Hyderabad	December 01-02, 2022	IIT, Madras
11.	Dr. Y.R.S. Rao, Scientist- 'G' delivered a keynote lecture in the District Level workshop on Climate Resilient Agri-Allied Sector "Climate change Adaptation and Mitigation"	January 27, 2023	Ambajipet, Andhra Pradesh
12.	Sabyasachi Swain, Scientist- 'B' attended the training	February	IIT, Kharagpur

	Session on "Geomatics and Data Analytics using Open Source - GEE"	16, 2023	
13.	Sabyasachi Swain, Scientist- 'B' presented two keynote lectures on the topic "Impacts of Climate Change on Water Resources" and "Insights on Precipitation Variabilities" during the "World Water Day- 2023" programme at the Dept. of Civil Engg., Govt. Engg. College (GEC) Banka, Bihar	March 22, 2023	GEC, Banka, Bihar

TRAINING COURSES/WORKSHOPS ORGANISED DURING 2023-24 (upto August)

S.No.	Title of the course	Date	Venue	No. of Participants
1.	Second TOT training course "Usage and Applications of DSS(PM)"	April 17-28, 2023	NIH, Roorkee	25
2.	Training course on "Hydrological Modeling using SWAT+" during May 22-27, 2023, for various academic and research institutions, including researchers, scientists, faculties, scholars and other PG students.	May 22-27, 2023	Roorkee	35
3.	Organized internship training programme on "Exposure to Various Research Activities of NIH Roorkee" for B. Tech (Civil Engineering) students from NIT Raipur.	May 8-12, 2023	Roorkee	08
4.	Training Workshop on "1. Use of Geospatial Technologies in Flood Management and Erosion Control" organised collaboratively by NIH and NEHARI, Brahmaputra Board	May 8-12, 2023	NEHARI, Guwahati	20
5.	Training Program on "Hydrological Modelling" organised collaboratively by NIH and NERIWALM	May 15-19, 2023	NERIWALM, Tezpur	20
6.	Training cum final presentation of the project entitled "Study of Various Possible Scenarios for Understanding the Long-term Effect of en-route Canal Irrigation for Proposed Mahanadi-Godavari Link" in the 2nd Meeting of Sub - Committee for "Comprehensive Evaluation and System Studies on Interlinking of Rivers", Chaired by Sh. A. B. Pandya, Secretary General, ICID and former Chairman, CWC	June 30, 2023	Roorkee	40
7.	Training Course on the topic "TUFLOW Hydraulic Modelling: Flood Inundation Modelling (1D, 2D & 3D) including Coastal and Urban Floods, Sediment Transport, and Water Quality" organized by NIH Roorkee in collaboration with TUFLOW India.	June 26-28, 2023	Roorkee	10
8.	Training course on "Hydrological and	July 31 to Aug 4,	WALMI,	38

	Hydrodynamiv Modeling using HEC HMS and HEC RAS” for Water resources Engineers of UP under NHP (DRr AKL, Jaiswal, & JPP)	2023	Lucknow	
9.	“Watershed & Waterbodies Management” organized jointly with North Eastern Hydraulic and Allied Research Institute (NEHARI)	August 21-25, 2023.	NEHARI, Guwahati	22
10	“Hydrological and Hydrodynamic Modelling Using HEC HMS & HEC RAS” under NHP	July 31 to August 4, 2023	WALMI Lucknow	38
11	Training cum orientation programme for newly appointed scientists	August 28-September 01, 2023	NIH Roorkee	18

APPENDIX 77.4.4

PROGRESS OF LABORATORY WORK
DURING THE PERIOD
JULY 2022 – MARCH 2023
&
APRIL – JULY 2023

1. **Water Quality Laboratory**
2. **Nuclear Hydrology Laboratory**
3. **Soil-Water Laboratory**

Chemical and Bacteriological Analysis of Water Samples in Water Quality Laboratory for the period between July, 2022 to July, 2023

	No. of samples of Division	**No. of samples of Regional Centre**	**No. of samples of Outside Agencies on payment basis**
Physico-chemical analysis	2068	-	12
Bacteriological analysis	360	-	12
Metal analysis	3110	-	12
Pesticides, PAH, PCBs & VOCs analysis	1215	-	12 (VOCs)
Total analysis	**6753**	-	48

Soil Water Laboratory
Laboratory Analysis is carried out during the period June 2022 to July 2023

Sl. No.	**Name of the studies**	**No. of Samples**	**Parameters Measured**
1	Water quality assessment of southwest Punjab emphasizing carcinogenic contamination and their possible measures (PDS, Punjab) & influence of anthropogenic factor son river ganga in the stretch from Rishikesh to Haridwar (Internal study)	53	Percentage of Carbon, Hydrogen, Nitrogen and Sulphur in soil
2	Pine Oak ecosystem interaction with water climate chemistry.	15 9	Permeability, bulk density. % Soil moisture, dry density, Sat Pore space percentage. Grain size
3	Developing alternate water supply & management strategies in Arsenic effected area in the central Ganga basin	75 199	Soil Texture, Percentage of Carbon, Hydrogen, Nitrogen and Sulphur in soil, As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
4	Seasonal characterizations of Gangotri glacier melt runoff & simulation of stream low variation under different climate scenarios.	560	Percentage of Carbon, Hydrogen, Nitrogen and Sulphur in soil
5	Hydrological study to assess the impact of mining activities in the around the Dariba mine area of Hindustan zinc Ltd. in Udaipur district (Rajasthan)	27 71	Soil texture, bulk density and porosity, Soil moisture retention curve, As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
6	Enhancing food and water security in arid region through improved understanding of quality quantity and management of blue, green and gray water.	23	Soil moisture retention curve, wilting point, bulk density and Soil texture.
7	Soil texture analysis for Joshimath	1	Soil texture
8	Changing the fate of Hindon river by evaluating the impact of agriculture on water balance: Developing the template for cleaner Ganga river.	299	Soil texture

9	Conjunctive management of water resource in IGNP command	15	Soil texture, soil moisture retention curve, pH, EC
10	Calculation of rainwater harvesting potential and performance of recharge wells	9	Bulk density, soil moisture retention curve, soil texture.
11	Ground water investigation of Rana Sugars Ltd., Buttar Seviyan area of Amritsahar, Punjab	17	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
12	Integrated study of GW dynamic in the coastal aquifer of west Bengal for sustainable GW management	186	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
13	Chemical & Isotope characterization of deep aquifer: GW of middle Ganges Basin	37	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
14	Hydro-geological study in Meja, Prayag raj, UP	126	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
15	Analysis of water quality for NIH colony	11	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
16	Integrated management of water resources for quantity and quality in Upper Yamuna Basin Project.	268	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
17	Assessment of dissolved radon concentration in GW of Haridwar & Dehradun	95	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
18	Understanding Arsenic mobilization in GW of Haridwar and Formulating remediation	117	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
19	Ph.D entitled "Thesis on Arsenic contamination in groundwater in and around Varanasi"	199	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
20	Hydrological study to assess the impact of mining activities in the around the Rampura Agucha mine area of Hindustan zinc Ltd. in Bihilwara district (Rajasthan)	24	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
21	CS-252/2022-23/GWHD Consultancy	13	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.
22	Conjunctive management of water resource in IGNP command	16	As, Cd, Cu, Cr, Mn, Zn, Fe, Al, Pb and Ni.

MINUTES OF THE 53rd MEETING OF THE WORKING GROUP OF NIH

NATIONAL INSTITUTE OF HYDROLOGY, ROORKEE

Minutes of the 53rd Meeting of NIH Working Group
(16-17 March, 2023)

The 53rd meeting of NIH working group was held during 16-17 March, 2023 at Roorkee under the Chairmanship of Dr. Sudhir Kumar, Director (NIH). A list of participants of the meeting is given in Annexure-I.

ITEM NO. 53.1: OPENING REMARKS BY THE CHAIRMAN

The Chairman, WG, welcomed the WG members and the Scientists of NIH. He informed that the objective of this meeting is to review the progress of 2022-23 and to formulate the work program of 2023-24. Before initiating proceedings of the WG meeting, the Chairman requested the WG members to give their general observations, suggestions and remarks on the scientific activities of the Institute. These are summarized below:

S.N.	Member	Suggestion(s)
1.	Prof. A.P. Dimri	▪ To explore applicability of Geomatics & GNSS in various studies ▪ Try to prepare basin level atlas ▪ Suggestion for supervision of doctorate and Master Level Courses by Scientists and initiation of 2 week master student's program in the domain of hydrology and water resources
2.	Dr. Bhishm Kumar	▪ Develop a database and share it in the public domain ▪ Burning issues related to water should be emphasized while designing any research proposal ▪ R&D dissemination for Society
3.	Dr. Manoj P. Samuel	▪ Research should be executed in the interest of society and suggestion to develop Models/Mobile Apps for common people. ▪ Need of Commercial Wing for Business development related to water sector R&D activities ▪ Suggested collaboration of new NIH-RC, Jodhpur with CAZRI (Jodhpur) in R&D and other activities ▪ Suggestion for data base and data sharing
4.	Prof. Ramakar Jha	▪ While doing research, drone technology may be used in inaccessible areas ▪ Make efforts to patent the software developed by the Institute ▪ Re-employment of retired scientists in NIH to utilize their rich experience/knowledge for Institute's R&D activities
5.	Dr. Vijay Kumar	▪ Suggested for collaborative work with MOES in the area of Cryosphere/Glacier Studies as well as to increase collaboration with Intl. organizations. ▪ Creation and management of data base for further collaborative studies
6.	Sh. Sudhindra Mohan Sharma	▪ Suggestion for public centric R&D, develop public relations and translation of benefits to society and states ▪ Works for enhancing drinking water security as per mandate of the Ministry
7.	Dr. (Mrs.) Sadhana Malhotra	▪ Very enriching experience in NIH ▪ Dissemination of R&D Output/Press release of NIH Studies ▪ To assess impact of training programs
8.	Prof. K.K. Singh	▪ Data repository and sharing ▪ Separate Cell for Software Development in NIH ▪ Engagement of retired scientists ▪ Research for the common man ▪ Suggestion for B. Tech/M. Tech. Internship Programs ▪ Need to rename WRS Division

9.	Prof. AK Saraf	▪ Appreciation for new NIH centre at Jodhpur ▪ Re-employment of NIH Scientists
10.	Dr. Prashant Rai	▪ Suggested more collaboration with CGWB in studies and to work in agricultural areas

After brief introduction about NIH activities, the Chairman asked the Member-Secretary to take up the agenda of this meeting.

ITEM No. 53.2: CONFIRMATION OF MINUTES OF 52nd MEETING OF WORKING GROUP

The 52nd meeting of the Working group was held during 12-13 April, 2022. The minutes of the meeting were circulated to all the members and invitees vide letter No. **RMOD/WG/NIH-10 dated 25th May, 2022**. The members confirmed the minutes of the 52nd Working Group meeting.

ITEM No. 53.3: ACTION TAKEN ON THE DECISIONS/RECOMMENDATIONS OF THE PREVIOUS WORKING GROUP MEETING

Er. Omkar Singh, Scientist G & Head (RMOD)/Member Secretary (WG) gave a brief account of the actions taken on the recommendations/ decisions of the 52nd working group meeting.

ITEM Nos. 53.4 & 53.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2022-23 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2023-24

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2022-23 and also to present the proposed studies for F.Y. 2023-24. Accordingly, the progress of various studies and sponsored projects, and proposal for new studies and projects during 2023-24, were presented by all Scientific Divisions during the two-day deliberations of the Working Group. The Division wise minutes of each study/project presented during the meeting are given below:

ENVIRONMENTAL HYDROLOGY DIVISION

The overview of the technical activities of Environmental Hydrology Division (EHD) was presented by Dr. R.P. Pandey, Scientist 'G' & Head. The Working Group was appraised about the scientific manpower, status of completed and ongoing studies, consultancy projects, publications, and technology transfer activities. Subsequently, the scientists of the Division were invited to present the completed studies, progress of ongoing internal studies and proposed new studies. The Comments/suggestions of Working Group members are summarized below.

Progress of Work Program for 2022-23

S. N.	Title of Project/Study	Recommendations/Comments
Internal Studies (Ongoing)		
1.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	Dr. Bhishm Kumar suggested to involve state groundwater department in the study. Dr. Sharma noted for compliance.
2.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Dr. Bhishm Kumar (Ex. Scientist, NIH) suggested to correlate the Arsenic (As) in the GW with other relevant parameters. Dr. Sudhir Kumar, Director (NIH) suggested to collect and analyze sediments samples for trace metals particularly, Arsenic in Solani river.

3	Simulation of Non-Point Source Pollution Processes in Song River	There were no specific comments/suggestions.
	Sponsored Projects (Ongoing)	
1.	Water Efficient Irrigation by Using SCADA System for Medium Irrigation Project (MIP) Shahnehar	PI has reported that further extension would be required from NHP to complete field observations.
2.	Anaerobic co-digestion of wastewater treatment plant sludge and organic fraction of municipal solid waste: Effect of thermal-chemical pretreatment on process performance and microbial community development	Dr. Bhishm Kumar (Ex. Scientist, NIH) and other working group members suggested to look after the economic benefits of the work.
	Sponsored /Collaborative Projects (Ongoing)	
1.	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	PI reported that the study is in progress.
2.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	PI reported that this study is in progress in collaboration with other institutions
3.	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	Co-PI reported that this study is in progress with IIT Roorkee
	Internal Studies (New)	
1.	Hydrological Studies for the Conservation of Rewalsar Lake, H.P.	The queries raised by Prof. A. K. Saraf and Prof. Ramakar Jha related to methodology/data availability were replied by the PI. The WG agreed the objectives and scope of the study.
2.	Comprehensive evaluation of disinfection units of STPs in Ganga basin: Formation & Control of emerging oxidation precursors.	The WG appreciated the novelty of work to be taken up in this study. The WG agreed the objectives and scope of the study.

Recommended Work Programme for the Year 2023-24

S. N.	**Title of Project/Study**	**Study Team**	**Duration**	**Funding (Rs. Lakh)**
Internal Studies (Ongoing)				
1.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	Dr. M. K. Sharma, Sc. F (PI) Dr. Suhas Khobragade, Sc. ‘G’ Dr. Rajesh Singh, Sc. ‘D’ RC Kakinada: Dr. YRS Rao, Sc.G CGWB-Hyderabad	2 Years (04/22-03-24)	NIH
2.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Dr. Rajesh Singh, Sc. D (PI); Dr. R. P. Pandey, Sc. G; Dr. Sumant Kumar, Sc. D; Dr. Pradeep Kumar, Sc. D; Dr. M. K. Sharma, Sc. F; Dr. V. K. Tyagi, Sc, D; Dr. Kalzang Chhoden, Sc. C	3 Years (07/21-06/24)	NIH
3.	Simulation of Non-Point Source Pollution Processes in Song River	Dr. Pradeep Kumar, Sc. D (PI) Dr. M.K. Sharma, Sc. F Dr. Rajesh Singh, Sc. D	4 Years (11/19-10/23)	NIH

Internal Studies (New)				
4.	Hydrological Studies for the Conservation of Rewalsar Lake (H.P.)	Dr. Kalzang Chhoden, Sc. C, (PI); Dr. Rajesh Singh, Sc. D; Dr. R. P. Pandey, Sc. G; Dr. Pradeep Kumar, Sc. D; Dr. Vinay Kumar Tyagi, Sc. D; Er. Omkar Singh, Sc. G; Dr. Shuhas Khobragade, Sc. G; Dr. D.S. Malik, Professor, GKU, Haridwar	3 Years (04/23-03/26	NIH
5.	Comprehensive evaluation of disinfection units of STPs in Ganga basin: Occurrence and control the formation of emerging oxidation precursors	Dr. Vinay Kumar Tyagi, Sc. D (PI); Dr. Rajesh Singh, Sc. D; Dr. Mukesh K. Sharma, Sc. F Dr. Pradeep Kumar, Sc. D; Er. J. P. Patra, Sc. D; Dr. Kalzang Chhoden, Sc. C; Dr. R.P.Pandey, Sc. G	3 Years (04/23-03/26)	NIH
Sponsored Projects (Ongoing)				
1.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	Dr. R. P. Pandey, (PI) Er. J. P. Patra, Dr. Rajesh Singh Sh. N. K. Bhatnagar	3 Years (12/17-05/23). Further extension is needed to complete field based tasks	NHP (75.00)
2.	Anaerobic Co-digestion of Thermochemically Pretreated Organic Fraction of Municipal Solid Waste and Sewage Sludge: Effect on Process Performance and Microbial Community Development	Dr. Vinay Kumar Tyagi, Sc, ‘D’ (PI)	5 Years (2018-2023)	DBT (106.00)
Collaborative Projects (Ongoing)				
1.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	Dr. Rajesh Singh (PI) Dr. R.P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 Years (07/21-06/24)	BHU
2.	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	Dr. Vinay Kumar Tyagi, Sc, ‘D’ (Co-PI) Dr. A.A.Kazmi (PI, IITR)	02 Years (01/22-12/23)	CPCB-NMCG
3.	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	Dr. Vinay Kumar Tyagi, Sc, ‘D’ (Co-PI) Dr. A.A.Kazmi (PI, IITR)	4 Years (03/20-02/24)	DST

GROUNDWATER HYDROLOGY DIVISION

Dr. M. K. Goel, Sc. “G” and Head, Groundwater Hydrology Division (GHD) made a brief presentation about the present manpower of the division and attached Soil-Water laboratory, thrust areas of the division, work program and major achievements during the year 2022-23 and the proposed work program for 2023-24. It was informed that in addition to progress in various studies and sponsored projects, three software have been developed during the year and three new internal studies have been planned. Subsequently, detailed discussion on various studies were made by the respective Scientists (PIs) of various studies. The discussion on these studies is summarized below:

S. No.	Title of Project/Study	Recommendations/Comments
Internal Studies (Completed)		
1. NIH/GWH/NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Director desired to make a presentation for the CGWB and DoWR, RD & GR officials.
Internal Studies (Ongoing)		
1. NIH/GWH/NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	No specific comments were made by the WG Members.
2. NIH/GWH/NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Dr. Dimri suggested to analyze the water-logged area before and after the introduction of IGNP. PI agreed to the suggestion.
3. NIH/GWH/NIH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	No specific comments were received from the members.
Sponsored Projects (Completed)		
1. NIH/GWH/PDS/17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana-Possible Remedy and Resilience Building Measures	Not Presented
2. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Not Presented
3. NIH/GWH/APN/22	Capacity Development Program on Site Suitability Mapping for MAR under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools	PI presented the ***PraJal*** portal developed in the study. No specific comments were made by the WG Members.
Sponsored Projects (Ongoing)		
1. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab -Groundwater resilience and adaptation to future changes in climate and water resource demands	Dr. S. M. Sharma advised to look the ownership of the installed piezometers in this project. PI noted.
2. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Not Presented
3. NIH/GWH/DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	No specific comments were received from the members.
4. NIH/GWH/CCRBF/20-23	Expansion of Indo-German Competence Centre for Riverbank Filtration	The members appreciated for the efforts and no specific comments were offered.
5.	Partitioning Evapotranspiration into Evaporation and	Prof. Dimri and Dr. M. Samuel suggested to

NIH/GWH/DST/21-24	Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	validate the results. PI replied for the queries.
Internal Studies (New)		
1. NIH/GWH/ 22-24	Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India	Dr. Bhishm Kumar supported the study & expressed need of isotope-based studies for Jammu & Kashmir. The WG agreed the proposal.
2. NIH/GWH/ 23-24	Development of Archive of Soil Hydraulic Characteristics	Dr. Bhishm Kumar and other members felt the need of such type of studies to disseminate outcomes for wider application/use/replication for other labs. The WG agreed the proposal.
3. NIH/GWH/ 23-25	Enhancement and application of NIH_WISDOM	There were no specific comments and WG agreed the proposal.

Finally, on the advice of the Director, Dr. M. K. Goel made a brief presentation about the NIH_ReSyP software developed at NIH for comprehensive reservoir-related analysis and its applications for the Upper Krishna basin. Dr. M. Samuel asked whether variable downstream channel capacity is being considered in the flood simulation module. It was informed that based on the observations from recent flooding in Kerala, variable downstream channel capacity option has been included. Dr. Bhishm Kumar suggested for its application and testing with some reservoir analysis for foreign reservoirs. He shared the contact details of Dr. Nachiappan who is working in Australia on reservoir-related aspects and may be helpful for such applications. The members appreciated for the efforts. The final proposed work program for the year 2023 – 24 is given below:

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-24

S. No.	Title of Project/Study	Project Team	Duration	Funding
Internal Studies (Ongoing)				
1. NIH/GWH/ NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar (PI), Surjeet Singh, Rajesh Singh, Gopal Krishan, S. S. Rawat, M. K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel	3 years (04/22 – 03/25)	NIH
2. NIH/GWH/ NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Surjeet Singh, Gopal Krishan, Sumant Kumar, Nidhi Kalyani	2 years (04/22 – 03/24)	NIH
3. NIH/GWH/ NIH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	Nidhi Kalyani (PI), Anupma Sharma, Nitesh Patidar, Sumant Kumar	2 years (04/22 – 03/24)	NIH
Sponsored Projects (Ongoing)				
1. NIH/GWH/ BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab -Groundwater resilience and adaptation to future changes in climate and water resource demands (title modified by funding agency)	Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao; *BGS-UK:* Dr. Dan Lapworth, Dr. Alan MacDonald, Dr. Daren Goody	5 years (12/17-11/22, ext. till Nov. 2024)	BGS: UK

2. NIH/GWH/ CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) Sanjay K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, S. Kumar, P. K. Mishra, V. Singh, N. Patidar, N. Kalyani **Partners***:* HIWRD, UPGWD, UYRB, CWC	4 years (04/18-01/24)	NHP
3. NIH/GWH/ DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (PI) Gopal Krishan, Nitesh Patidar, P. K. Mishra (**Lead:** CAZRI Jodhpur, **Partners**: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 01/24)	DST
4. NIH/GWH/ CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator)	3 years (07/20 – 06/23)	Federal M/o Edu. & Res., Germany
5. NIH/GWH/ DST-SERB/21-24	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), M. S. Rao	3 years (04/21 – 03/24)	DST-SERB
Internal Studies (New)				
1. NIH/GWH/ 22-24	Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India	Gopal Krishan (PI) M. S. Rao; *SKUAST-Srinagar* Rohitashv Kumar	1.5 years (09/22 – 03/24)	NIH
2. NIH/GWH/ 23-24	Development of Archive of Soil Hydraulic Characteristics	Surjeet Singh (PI); Nitesh Patidar; M. K. Goel; Anju Chaudhary; Anupma Sharma	1 year (04/23- 03/24),	NIH
3 NIH/GWH/ 23-25	Enhancement and application of NIH_WISDOM	Nitesh Patidar (PI), D. S. Bisht, M. K. Goel, T. Thomas, Sunil Gurrapu, Anupma Sharma, Surjeet Singh	2 years (10/23 – 09/25)	NIH

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr. Suhas Khobragade, Scientist-G and Head of the H. I. Division presented the brief details of the Division including the scientific staff strength and infrastructure. He briefly introduced about the scientific work of the Division and the various studies being carried by the Division, along with details about the publications by the Division and analytical work carried out at the Nuclear Hydrology Laboratory. The progress of each individual study for the year 2022-23 and the proposal for the new studies was presented by the respective P.I. of the study. Since Sh Hukam Singh, Sc. 'B' got retired the presentation of his completed study was made on his behalf by Dr. M. Someshwar Rao, Sc-F. Studies already presented under NHP were not presented. The comments/actions suggested by the working group for various studies are given below:

SN	Title of Project/Study	Recommendations/Comments
Internal Studies (Completed)		
1.	Assessment of dissolved radon concentration in groundwater of Uttarakhand	No specific comments/suggestions received

Internal Studies (Ongoing)		
1.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	Not presented
2.	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	No specific comments/suggestions received
Sponsored Projects (Completed)		
1.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	Not presented
2.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Not presented
3.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	Not presented
4.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Not presented
5.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	Not presented
6.	Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh	Not presented
7.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	Video Presentation
Sponsored Projects (Ongoing)		
1.	Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures	Not presented
2.	Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river	No specific comments/suggestions received
Internal Studies (New)		
1.	Developing a Stable Isotopic Analysis System for analyzing the dissolved Nitrates in water	No specific comments/suggestions received
2.	Geo-Hydro-Chemical and Isotopic Aspects of Occurrence of Springs: A case study from the major settlement areas of Bhagirathi basin, Uttarakhand, India	No specific comments/suggestions received
3.	Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies	Dr. Praveen Thakur suggested to modify the title from feasibility to application since it is not a feasibility study. Sh. Sudhindra Mohan Sharma suggested to change the objectives as present objective are more like work elements
4.	Sedimentation and Water Quality Studies of Phulahar Lake, Pilibhit (U.P.)	No specific comments/suggestions received

Head (HID) also informed about the technology transfer activities organized by the Division during 2022-23.

Table : Details of training Courses/Workshops organised by the Division during 2022-23

S. N.	Topic	Duration	Coordinator	Venue	Participants
1.	Scientific Data Collection and Processing Techniques for Springshed Management and Rejuvenation	19-22.12.2022	Dr. S. M. Pingale & Dr. S. S. Rawat	IRI, Roorkee	24
2.	Springshed Management	13-15.12.2022	Dr. S. S. Rawat	DoLR, Kohima, Nagaland	47
3.	Scientific Data Collection and Techniques for Springshed Management and Rejuvenation	06-09.09.2022	Dr. S. S. Rawat	NEHARI, Guwahati	28
4.	Tools and Techniques for Springshed Management	03.09.2022	Dr. S. S. Rawat	Govt. Degree College, Udhampur (J&K)	80
5.	Groundwater contaminant transport monitoring & modelling	23 to 27.05.2022		Online Under NHP – PDS - 19	40
6.	Stakeholder Meeting Under DST-NWO Hindon Project	15th Feburary,2023	Ms. Anjali,	c-Ganga office, New Delhi.	10

RECOMMENDED WORK PROGRAMME OF FOR THE YEAR 2023-24

S. N.	Title of Project/Study	Study Team	Duration	Funding
Internal Studies (Ongoing)				
1.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	S.D.Khobragade (PI); Dr. Vishal Singh, Sudhir Kumar	3 years (04/22-03/25)	NIH
2.	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	Soban Singh Rawat, (PI); Sudhir Kumar, Santosh M. Pingale; P K Mishra; D. S. Bisht; Rajesh Singh	3 years (04/22-03/25)	NIH
Internal Studies (New)				
1.	Developing a Stable Isotopic Analysis System for analyzing the dissolved Nitrates in water	M. S. Rao(PI) Vishal Gupta	1 and ½ years (04/23-09/24)	NIH
2	Geo-Hydro-Chemical and Isotopic Aspects of Occurrence of Springs: A case study from the major settlement areas of Bhagirathi basin, Uttarakhand, India	Dr. Soban Singh Rawat, (PI); S. D. Khobragade; M K Sharma; M S Rao; S.M. Pingale; P. K. Mishra	3 years (04/23- 03/26)	NIH

S. N.	Title of Project/Study	Study Team	Duration	Funding
3	Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies	S.M. Pingale (PI) Soban Singh Rawat, S. D. Khobragade Rajeev Gupta	2 Years (04/23- 03/25)	NIH
4	Sedimentation and Water Quality Studies of Phulahar Lake, Pilibhit (U.P.)	Rajeev Gupta (PI) S. D. Khobragade S.M. Pingale	2 Years (04/23- 03/25)	NIH
Sponsored Projects (Ongoing)				
1.	Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi M. K. Sharma Partner: CGWB (Delhi unit)	3½ years (11/19 – 06/23)	NHP-PDS
2.	Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river	Sudhir Kumar, (Proj. Coordinator), M. K. Sharma, (PI), Suhas Khobragade, Anjali, Vishal Singh, SM Pingale, Nitesh Patidar, Surjeet Singh.	5 Years (04/22 – 03/27(	DST

SURFACE WATER HYDROLOGY DIVISION

Dr. A.K. Lohani, Sc G & Head, Surface Water Hydrology Division presented the various activities of the division. The number of research papers published in various journals, lectures delivered in various training courses and number of M.Tech./Ph.D. students guided/under guidance during the period were also reported. The concerned PI of the study presented the progress of his/ her completed and new internal studies during the working group meeting. Sponsored studies are not presented. The record of discussions for the respective study is given below:

Work Program for the Year 2022-23

S. N.	Title of Project/Study	Status and Recommendations/ Suggestions
Internal Studies (Completed)		
1.	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan	Completed. No specific action suggested.
2.	Uncertainty in rating curves and discharge estimation	Completed. There were no specific comments from the members on the study.
3.	Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A	Completed. No specific action was suggested.
4.	Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution	Completed. No specific action was suggested.
Sponsored Projects (Completed)		
1.	Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP)	Completed. The study was reported.
Internal Studies (Ongoing)		
1.	Development of Cloud Data Based Integrated	No specific action was suggested.

	Framework to Forecast Flood for Efficient Operation of Reservoirs	
2.	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	No specific action was suggested.
3.	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	No specific action was suggested.
4.	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	No specific action was suggested.
5.	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	The study was not presented.
6.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	PI requested for provision of a resource person for the study as well as extension of the study by six months (up to April 30, 2024) and WG approved the extension. No other specific comments were received.
7.	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin	No specific action was suggested.
Sponsored Projects (Ongoing)		
1.	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts	The study was not presented.
Internal studies (New)		
1.	Estimation of confidence intervals of index flow duration curves	PI presented the objectives and scope of the proposed study. There were no specific suggestions/comments from the members.
2.	Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels	PI presented the objectives and scope of the proposed study. No specific action was suggested.

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-24

S. N.	Title of Project/Study	Study Team	Duration	Funding
Internal studies (Ongoing)				
1.	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	A. K. Lohani; R. K. Jaiswal J.P. Patra; P. C. Nayak Vishal Singh	2 Years (April 2022 – March 2024)	NIH
2.	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak; A. K. Lohani; J. P. Patra; Sunil Gurrapu; T. Thomas; Om Prakash; Jatin Malhotra	3 Year (July 2022 to June 2025)	NIH

3.	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	L. N. Thakural; M. K. Sharma; R. K. Jaiswal; J. P. Patra; P. K. Mishra; Nitesh Patidar; N. K. Bhatnagar; Jatin Malhotra; Anil Kumar Chhangani	2 Year (July 2022 to June 2024)	NIH
4.	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P.Patra; A. K. Lohani; Pankaj Mani; P. C. Nayak; Sanjay Kumar	3 Year (April 2022 to March 2025)	NIH
5.	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade; P.K. Mishra Sunil Gurrapu	3 years (April 2022 to March 2025)	NIH
6.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar; Jyoti Patil Rohit Sambare; Charu Pandey	2 Year (May 2022 to April 2024, after extn.)	NIH
7.	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin	R. V. Kale; A. K. Lohani J. P. Patra; D. Khurana	03 Years (September 2021-October 2024)	NIH
Sponsored Projects (Ongoing)				
1.	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI)	03 years (July, 2020 – June, 2023)	STARS (MHRD, GoI)
Internal studies (proposed)				
1.	Estimation of confidence intervals of index flow duration curves	Sanjay Kumar, Sunil Gurrapu; L. N. Thakural; J. P Patra	02 Years (April 2023 to March 2025)	NIH
2.	Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels	Sushil K. Singh	One Year (April 2023 to March 2024)	NIH

WATER RESOURCES SYSTEMS DIVISION

Dr. Sanjay K Jain (SKJ), Sc. G and Head, presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. Dr. Jain informed that a Centre for Cryosphere and Climate Change has been established in the Division. Thereafter, PIs of the respective studies presented the progress and the details is given below:

SN	Title of Project/Study	Recommendations/ Suggestions
Internal Studies (Completed)		
1.	Seasonal characterization of Gangotri Glacier melt runoff and simulation of stream flow variation under different climate scenarios	No specific comments were received.

2.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	No specific comments were received.
Sponsored Projects (Completed)		
1.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Not Presented
Internal Studies (Ongoing)		
1.	Monitoring and Hydrological Modelling of Henvel watershed in Lesser Himalaya	No specific comments were received.
2.	Spatio-temporal Water Availability under Changing Climate and Land use Scenarios in Wainganga River Basin	No specific comments were received.
3.	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	Dr. Ramakar Jha suggested to consider different climatic zones of India for selection of GCMs. Dr. Sanjay K Jain suggested to further discuss with Prof. Dimri in this matter.
Sponsored/Collaborative Projects (Ongoing)		
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Not presented.
2.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework	Not presented.
3.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework	Not presented.
4.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Not presented.
5.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	No specific comments were received in this collaborative study with IIRS.
6.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	Not presented.
Internal Studies (New)		
1.	Monitoring and Modelling of Gangotri watershed (Bhojwasa) under different Climate Scenarios	Dr. A. P. Dimri suggested to undertake the Mass Balance of Glacier.
2.	Glacier recurrence survey, Instrumentation and Modeling to study the Batal Glacier in part of Western Himalaya, India	Dr. Dimri suggested to see the other sites in the nearby area before finalisation of the site.

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-2024

SN	Title of Project/Study	Study Team	Duration	Funding (Rs. Lakhs)
Internal Studies (Ongoing)				
1.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya	M K Nema; Sanjay K Jain; P K Mishra;	3 years (08/20-07/23)	NIH (10.22)
2.	Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin	M K Nema; P K Mishra; Rahul Jaiswal	2 years (04/22-03/24)	NIH (9.72)
3.	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	Sunil Gurrapu; Nitesh Patidar; YRS Rao; R Venkata Raman; TVNAR Kumar	2 years (04/22-03/24)	NIH
Sponsored/Collaborative Projects (Ongoing)				
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Sanjay K. Jain P K Singh; M. Arora; A K Lohani; Vishal Singh	3 years (11/19-11/22) Extended up to 09/23	NMHS-MoEF (143)
2.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh; P K Mishra;	2 years (08/20-07/22) Extended up to 06/23	NHP (14.50)
3.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P K Mishra; P K Singh; Vishal Singh; P K Agarwal	2 years (04/21-06/23)	NHP (9.00)
4.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)	3 years (04/21-03/24)	NHP (25.00)
5.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	M K Nema; Sanjay K Jain; P. K. Mishra; Praveen Thakur (IIRS)	3 years (04/22-03/25)	IIRS (30.91)
6.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	P K Singh; Vishal Singh; Sanjay K Jain; Abhilash R.	3 years (04/22-03/25)	NHP (54.0)
Internal Studies (New)				
1.	Monitoring and Modelling of Gangotri (Bhojwasa) watershed under different Climate Scenarios	P K Mishra; Vishal Singh; Sunil Gurrapu; Manohar Arora; Sanjay K Jain; Jatin Malhotra	3 years (04/23-03/26)	NIH (57.0)

2.	Glacier recurrence survey, Instrumentation and Modeling to study the Batal Glacier in part of Western Himalaya, India	Vishal Singh; P K Mishra; Sunil Gurrapu; Sanjay K Jain; Manohar Arora; Jatin Malhotra	5 years (04/23-03/28)	NIH (71.0)

DETAILS OF TRAINING/ WORKSHOP DURING APRIL, 2022 - MARCH, 2023

SN	Title of Training Course/Workshop	Coordinators	Duration	Venue
1.	Twelve-day Training programme on "Water Resources Planning and Management" sponsored by META Nashik for the engineers of the Water Resource Department (WRD) of the Government of Maharashtra	Smt. D. Chalisgaonkar, Scientist G Er. P. K. Agarwal Scientist B	April 15-25, 2022	NIH, Roorkee
2.	Five-day Training on "National Hydrology Model" under the National Hydrology Project (NHP)	Dr. A. K. Lohani Scientist G Dr. S. K. Jain Scientist G	August 01-05, 2022	NIH, Roorkee
3.	Five-day online Training on "Hydrological Modeling using Soil and Water Assessment Tool (SWAT): Theory and Hands-on" sponsored by National Hydrology Project (NHP).	Dr. M. K. Nema Scientist D Dr. Vishal Singh Scientist D	August 22-26, 2022	NIH, Roorkee
4.	Five-day Training Course on "Application of Water Accounting Plus (WA+) Tool for Water Resources Management" under National Hydrology Project.	Dr. P. K. Mishra Scientist D Dr. P. K. Singh Scientist D	28 Nov. – 02 Dec., 2022	Kohima, Nagaland
5.	One-week Training Program on "Climate Change and Hydrological Impact Assessment"	Dr. Sunil Gurrapu Scientist C Dr. L N Thakural Scientist D	December 12-17, 2022	NIH, Roorkee
6.	Five-day Training Program on "Flood prone area mapping and modelling" for the Irrigation and Water Resources Dept., Govt. of Mizoram	Dr. Vishal Singh Scientist D	March 20 – 24, 2023	NIH, Roorkee

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

Er. Omkar Singh, Sc. G & Head, requested Dr. A. R. Senthil Kumar, Sc G to present the overview of the Division's activities and progress of studies during 2022-23. Dr. A. R. Senthil kumar presented tables showing the studies and outreach activities proposed for the F.Y. 2023-24. He also presented the progress of the studies/project along with the input of Er. Omkar Singh as given below:

SN	Title of Project/Study	Recommendations/Suggestions
Internal (Ongoing)		
1.	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand Region, Central India	WG was informed a need for extension up to June 2023 as conveyed by the PI.
2	Establishing hydrological regime and ecohydrological functions of Jhilmil Jheel Wetland, Haridwar District	The study was not presented due to long leave of PI on medical ground.
3	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat Region, Haryana	PI requested for extension of the study up to June 2023. There were no comments.

4.	Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun	Proposed to drop the study due to non-availability of requisite data/resource.
Sponsored (Ongoing)		
1.	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)-DST sponsored	Sponsored project was reported in WG meeting.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2023-24 (RMOD)

S.N.	Title of Project/Study	Study Team	Duration	Funding (Rs. Lakh)
Internal Study (Ongoing)				
1.	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sep 2020- Jun 2023	NIH
2.	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Sep 2020- Aug 2023	NIH
3.	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	A R Senthil Kumar (PI), Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Sep 2020- Jun 2023	NIH
Sponsored Projects (Ongoing)				
1.	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	Omkar Singh (PI), Rajesh Singh (Co-PI), V.C. Goyal (Ex- PI), Jyoti P. Patil, Rohit Sambare, Rajesh Agarwal, NR Allaka and Project Staff-HQ (IC-EcoWS) **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	DST-GoI (510)

Proposed Training/Webinar/Outreach Activities of RMOD (2023-24)

S.N.	Activity	Tentative Month	Place	Target Participants	Team
1.	5-days training on “Life Cycle Approach for Rejuvenation of Ponds and Lakes using Nature-Based Solutions” sponsored by NWM	May/ June 2023	Roorkee	R&D Institutes/ Univ./Govt. Organizations	J P Patil/AR Senthil Kumar, Omkar Singh, Rohit Sambhare, Rajesh Agarwal, NR Allaka
2.	Stakeholders workshop for Upper Dhasan Basin water resources assessment	May/June 2023	Bhopal	CWC, CGWB, State Govt. Dept., etc.	J P Patil, T Thomas, P K Mishra, Rohit Sambhare
3.	Five-day training program on “Hydrology of water bodies and their development under climatic uncertainty”	Jul/Aug 2023	Roorkee	Irrigation/PHE/ SWC departments	A. R. Senthil kumar, Jyoti Patil, Rohit Sambare, Santosh M Pingale, N R Allaka

Other Outreach Activities:

S.N.	Activity

1.	Preparation of short videos on R&D findings of selected NIH studies			
2 .	Coordination & Organizing activities under Azadi Ka Amrit Mahotsav-Phase 2.0			
3 .	Any other Outreach activity (exhibition) as assigned			
4.	Outreach activity on “Water Conservation & Water Security” in Schools	Oct/Nov/ Dec. 23	Schools (2 nos.)	Team: A. R. Senthil kumar, Omkar Singh, Rajesh Agarwal, N R Allaka

Sh. Omkar Singh thanked the members for their valuable contributions during deliberations in the Working Group meeting. The meeting ended with vote of thanks to the Chair.

ANNEXURE-I

List of Working Group Members who attended the 53rd WG meeting

1.	Dr. Sudhir Kumar, Director, NIH	Chairman
2.	Dr. Vijay Kumar, Ministry of Earth Sciences, New Delhi	Member
3.	Dr. Prashant Rai, CGWB, Dehradun	Member
4.	Dr. Praveen Thakur, IIRS, Dehradun	Member
5.	Prof. A.K. Saraf, IIT, Roorkee	Member
6.	Dr. Manoj P. Samuel, CWRDM, Kozhikode	Member
7.	Dr. Bhishm Kumar, IAEA (Retd.), Roorkee	Member
8.	Prof. Ramakar Jha, NIT, Patna	Member
9.	Prof. A.P. Dimri, Indian Institute of Geomagnetism, Mumbai	Member
10.	Dr. (Mrs.) Sadhana Malhotra, Mindspace, Dehradun	Member
11.	Sh. Sudhindra Mohan Sharma, Ex-Nodal Officer, MoDWS, Indore	Member
12.	Prof. K.K. Singh, NIT, Kurukshetra	Member
13.	Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH	Member
14.	Dr. M.K. Goel, Sc. G & Head GWH Division, NIH	Member
15.	Dr. A.K. Lohani, Sc. G & Head SWH Division, NIH	Member
16.	Dr. R.P. Pandey, Sc. G & Head EH Division, NIH	Member
17.	Dr. Suhas Khobragade, Sc. G & Head HI Division, NIH	Member
18.	Er. Omkar Singh, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from NIH

	EH Division		**SWH Division**
1.	Dr. M.K. Sharma, Sc. F	16.	Dr. S.K. Singh, Sc.F
2.	Dr. Rajesh Singh, Sc. D	17.	Dr. P.C. Nayak, Sc. F
3.	Dr. Pradeep Kumar, Sc. D	18.	Dr. Sanjay Kumar, Sc. F
4.	Dr. Vinay K. Tyagi, Sc. D	19.	Dr. Archana Sarkar, Sc. F
5.	Dr. Kalzang Chhoden, Sc. C	20.	Dr. L.N. Thakural, Sc. D
	GWH Division	21.	Dr. J.P. Patra, Sc. D
6.	Dr. Anupma Sharma, Sc. G	22.	Dr. R.V. Kale, Sc. D
7.	Dr. Surjeet Singh, Sc. F	23.	Sh. N.K. Bhatnagar, Sc. B
8.	Dr. Gopal Krishan, Sc. D	24.	Sh. Om Prakash, Sc. B
9.	Dr. Nitesh Patidar, Sc. C		**WRS Division**
10.	Ms. Nidhi Kalyani, Sc. B		
	HI Division	25.	Dr. Manohar Arora, Sc. F
11.	Dr. M.S. Rao, Sc. F	26.	Dr. P.K. Singh, Sc. D
12.	Dr. Soban S. Rawat, Sc. E	27.	Dr. Manish Nema, Sc. D
13.	Dr. Santosh M. Pingale, Sc. D	28.	Dr. P.K. Mishra, Sc. D
14.	Smt. Anjali, Sc. C	29.	Dr. Sunil Gurrapu, Sc. D
	RMO Division	30.	Dr. Vishal Singh, Sc. D
15.	Dr. A.R. Senthil Kumar, Sc. G		

In addition, Technical Staff have also participated during presentations of their respective Divisions.

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